· coefficient of thermal expansion · per cent ·

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MACHINE DESIGN

October 1953

inch per inch per degree Centigrade · fatigue

· elongation in 2 inches · moisture absorptio

bhn

· brinell hardness number · compression set · e

dielectric strength · pounds per square inch ·

psi

ct strength · maximum continuous service temp

%

ys

foot pounds · yield strength · specific gravity

Rockwell hardness ·

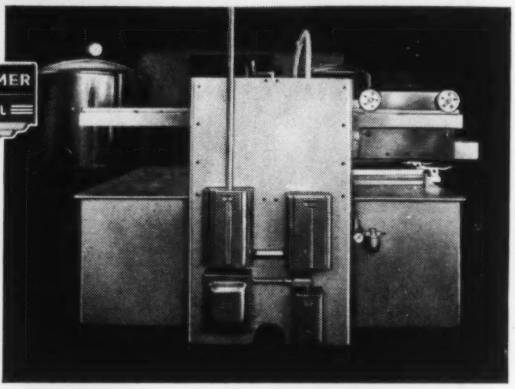
engineering materials

inch · tensile strength · transverse strength ·

CUTLER-HAMMER
MOTOR CONTROL
C-H

CHOICE OF THE LEADERS

THE MARK OF BETTER MACHINES



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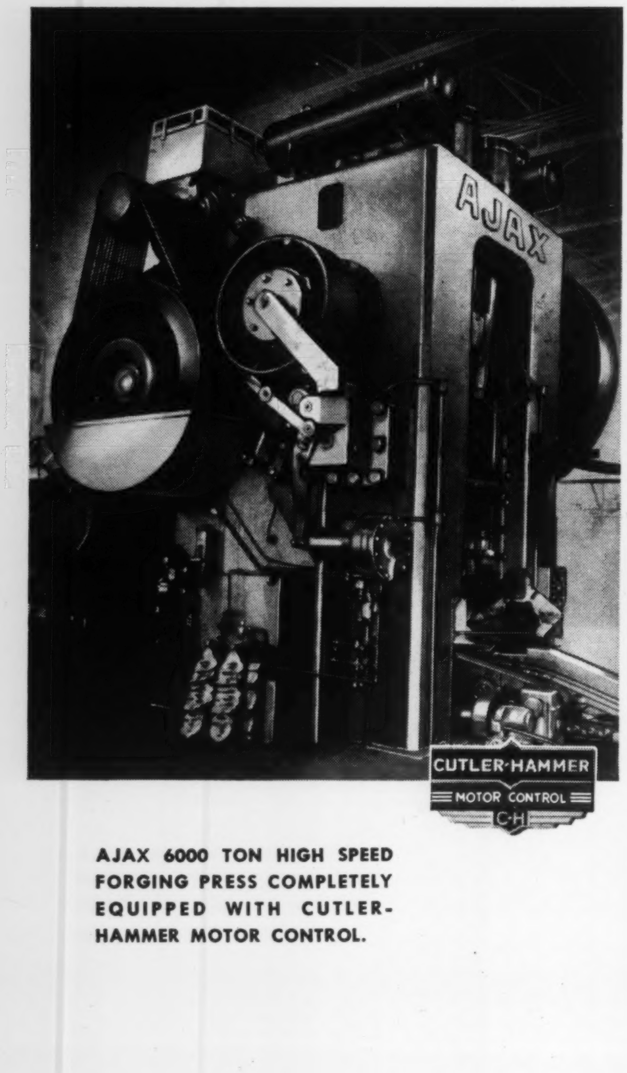

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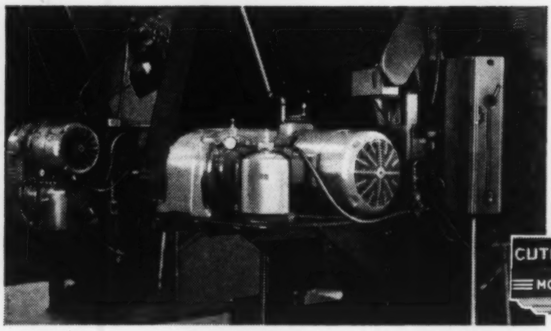

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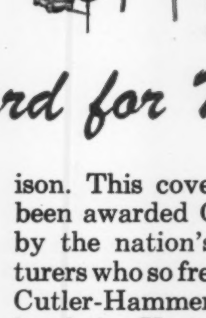

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FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

October, 1953
Vol. 25—No. 10

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Over the Board

A Promotion

Leo F. Spector, who has been an assistant editor of MACHINE DESIGN since December 1951, has been promoted to associate editor. His picture and biographical sketch appear on Page 434 of this issue. Incidentally, all the editors have been promoted from Page 4 to Page 3, beginning this month.

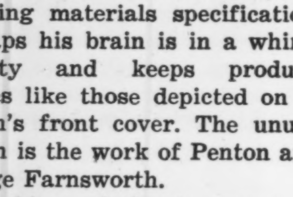
For "Men of Machines"

Want to display an emblem of your profession so people will know you're an engineer? Now you can obtain tie clasps, cuff links, money clasps — even earrings — featuring "genuine precision gears and bearings that actually turn." Man's World, of New York, offers them in either gold or silver plate at usual prices.

This Month's Cover

What does a design engineer dream about after a busy day studying materials specifications? Perhaps his brain is in a whirl of activity and keeps producing images like those depicted on this month's front cover. The unusual design is the work of Penton artist George Farnsworth.

Speaking of front covers, our May 1953 cover which depicted the face of a recording instrument has elicited this comment from J. G. Fleming of the Bristol Co.: "We realize that artists have considerable traditional liberty. However, the subject of instrument readability is perhaps one of the most critical areas in reducing the overall operation errors. The chart shown on the front cover would be normally classed as unreadable. It has divisions poorly divided and no contrast in line weights. An easy reading chart would have the range divided as recommended by psychologists and then further emphasized by contrasting line weights to distinguish the major steps from the minor. You would consider us negligent in our profession if we had not brought to your attention what we believe a critical factor in instrument design." Of course Mr. Fleming is absolutely right and the artistic license permitted in a cover design would not be acceptable in a functional illustration inside the magazine.



Who Wants To Be an Editor?

The following want-ad for a newspaper editor, which recently came to our attention, might serve with only minor modification as a description of the qualifications of a business paper editor:

"Wanted: Editor. Must be a top-flight photographer, diplomat, pussyfooter, politician and absolutely impartial in all thoughts and acts. Must be able to please all clubs, societies, organizations, cliques, groups, parts of groups, those who have individual thoughts on controversial issues, those who have thoughts on issues, and also those who haven't any thoughts on any issue but know that your thought on an issue is absolutely wrong. Must work at least 14 hours each day, sometimes seven days a week."

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Designing with engineering materials

• coefficient of thermal expansion • per cent •

inch per inch per degree Centigrade • fatigue st

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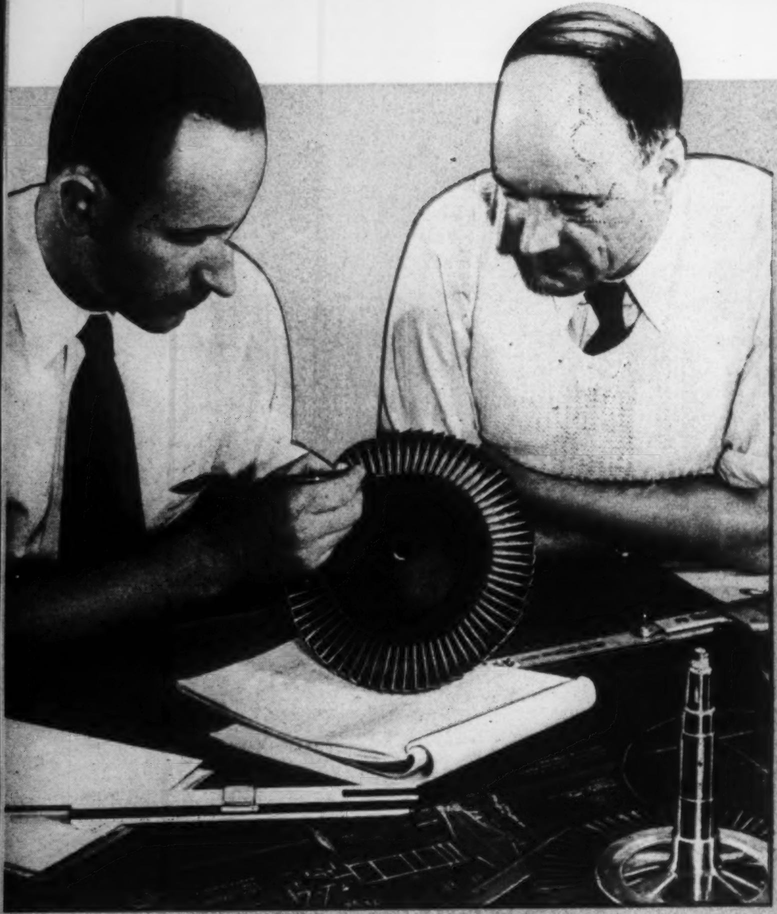
MACHINE DESIGN
OCTOBER, 1953

FEW areas of design offer more challenging opportunities for creative engineering talent than materials and their use. To develop effective, low-cost designs—not only for critical components, but also for everyday applications—a good deal of imagination must be used in materials selection, tempered with sound, practical judgment. New alloys and formulations, and new methods of utilizing standard materials, provide constant inspiration to the imaginative designer.

Application of a creative design viewpoint to engineering materials is also the keynote for this special section. In it are grouped articles dealing with several phases of materials design. But all have one feature in common—they are designed to inspire creative judgment and sound materials planning. Their one purpose is to help you use engineering materials to give substance to your ideas.

Colin Carmichael
EDITOR

PROPERTIES OF MATERIALS
HIGH-STRENGTH STEEL
SEALERS AS ENGINEERING MATERIALS
DATA CHARTS FOR PLASTICS
FINISHES FOR ALUMINUM
SPECIFICATION OF COLOR IN FINISHES



Photo, courtesy Boeing Airplane Co.

DESIGN properties

PART 1—PROPERTIES AND DESIGN

TRUE SERVICE characteristics of a material are usually expressed as properties data, with a reasonable degree of accuracy. Over many years, standard property tests have gained wide acceptance as easy and satisfactory ways of stating the major characteristics of a material. Properties are also the common language of materials evaluation and specification among designers, material producers, production men and purchasing agents.

But, as design tools, properties data have certain definite advantages and limitations which must be taken into account. An approximation is always involved when properties are used as indicators of true service characteristics, varying with the test, the material, and the purpose for which the information is to be used. Care, and appreciation of these limitations are necessary if most effective use is to be made of properties data.

If properties are to be used wisely for materials evaluation and planning, a perspective view must be taken of the properties of any one material against a background knowledge of other materials. The range of values of each property for all types of engineering materials must be known if a wise choice is to be made.

One of the main objectives of this and subsequent articles will be to throw further light on both of these areas; advantages and limitations of particular properties will be reviewed, and typical ranges of values outlined. The present article will consider the general use of properties in design.

Properties and Materials Planning

Factors entering into the final specification of a material are many and complex. Literally thousands of materials are available, from which a single material—adequate in all ways for the contemplated design—must be chosen. Information on properties is only one of the variables to be considered.

Materials Selection: Three considerations are fundamental in any choice of a material, and most selections involve a compromise in which each of the factors is carefully evaluated in proper proportion to the other two. These factors are:

# of materials

How properties data can be used more effectively for materials evaluation and selection

By ROBERT L. STEDFELD
Associate Editor, Machine Design

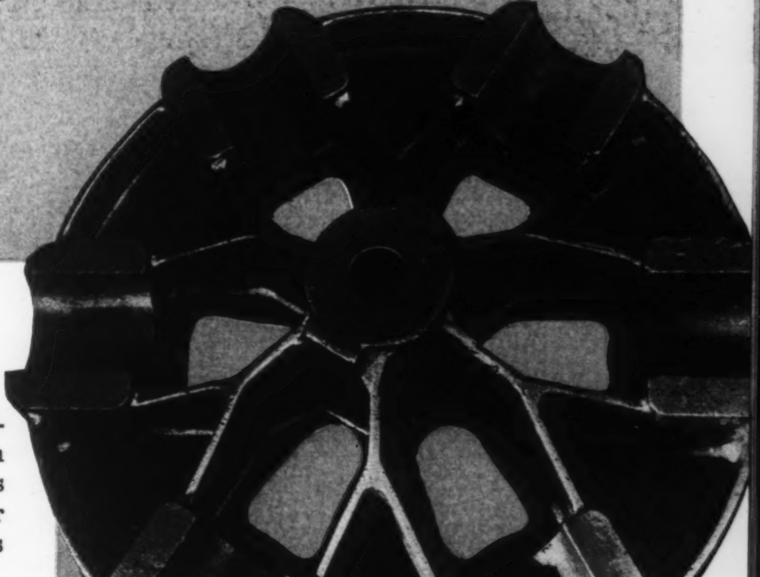
SERVICE FACTORS: The material must meet the performance requirements of the intended application in the expected environment. Thus, carbon steel springs would not be used in corrosive environments, nor would a thermoplastic plastic be used for applications involving excessive heat.

PRODUCIBILITY REQUIREMENTS: The material must be capable of manufacture by available processing techniques. Limitations in forgeability and formability, for example, have been deterring factors in extensive use of titanium.

COST AND AVAILABILITY: Primary cost of the material, and processing costs, must be within reason. Gold—soft, ductile and inert—makes an excellent gasket for some applications, but few people will pay $35 an ounce when other materials will suffice. The material must also be available for the intended use, a fact that has been very evident over the past decade.

Most materials selection is a matter of balancing the first two factors against the third. The material must stand up to expected (and sometimes unexpected) service demands or the design is a failure. It must also be producible by the method chosen.

But the material can be highly successful to the extent that it meets both requirements and still



Photo, courtesy American Brake Shoe Co.

Service requirements for this 200-pound fan hub which carries six blades include high tensile strength and fatigue strength. Used in cooling towers, the hub is subject to vibration from both the fan and large stationary diesels and heavy compressors in near-by pipe-line compressor stations. Ductalloy, a ferritic grade of ductile iron with a minimum 0.2 per cent offset yield strength of 45,000 psi and elongation of 10 per cent, was used for the application.

be inadequate in another respect—that of cost. Excess cost is an insidious factor that can easily intrude upon the best-intentioned design. Unnecessary strength, needless corrosion resistance and other unused attributes in materials—like excess baggage—cost money. However, a deficiency in necessary attributes also costs money in service failures and higher manufacturing costs. Thus, the best design from a materials-selection viewpoint is usually a compromise, an attempt to find the material that just meets the service and processing requirements.

Engineering properties are usually used as guides in determining the capability of a particular material to meet the first two requirements, service and producibility. Most tests, like the conventional tensile, fatigue, impact, and corrosion tests, are aimed at evaluating capacity under service demands. A few, such as "machinability" ratings, or the Olsen and Erichsen tests for determining "drawability," are aimed at evaluating the production possibilities of a material.

The word "aimed" is used advisedly. Property tests rarely hit the bullseye. There is seldom exact similitude between property tests and actual conditions, and the test can be trusted only so far as it correlates with the actual condition under consideration.

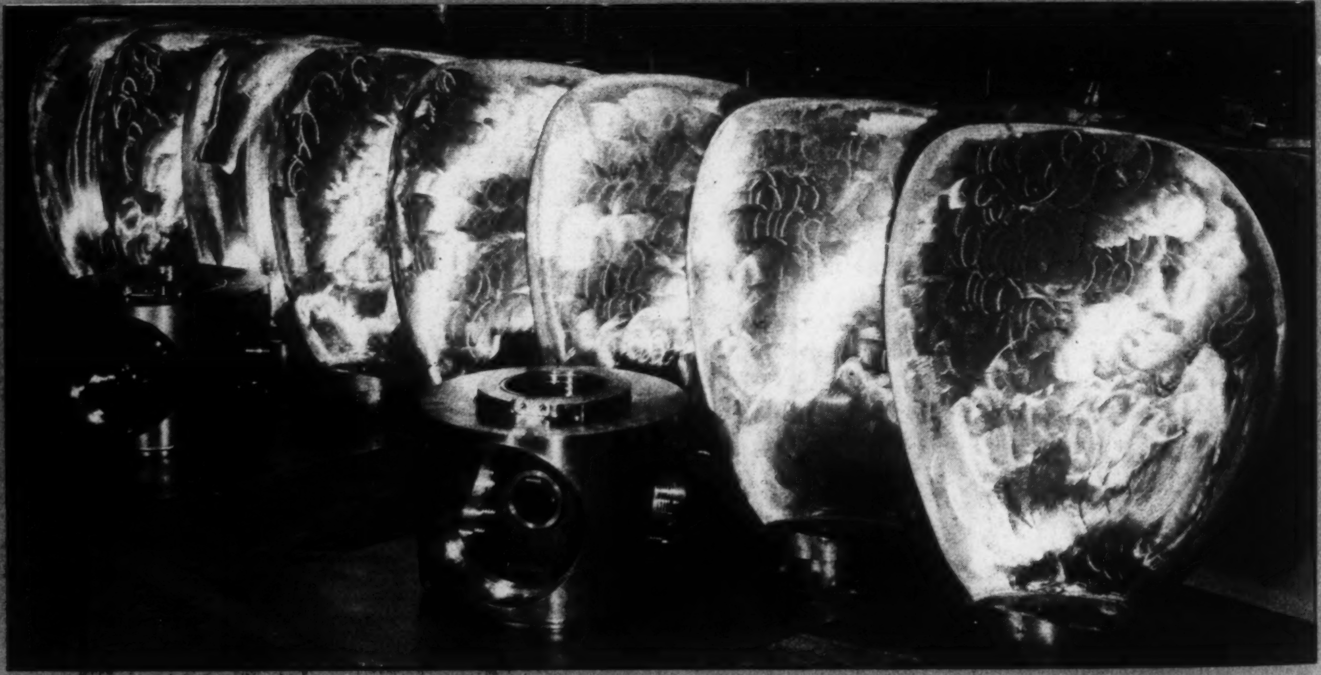
Methods of Evaluating Materials: Use of properties data, however, is only one method of evaluating the service and production capabilities of a material. Other routes also are taken:

1. Previous experience
2. Service testing
3. Simulated service testing
4. Evaluation by properties

Each has its advantages and disadvantages. Usually two or more are used in developing every design.

PREVIOUS EXPERIENCE: Familiarity with the service and processing capabilities of a material, although not truly a "method" of selection, colors all judgments of the relative worth of the material. In ex-

Photo, courtesy International Nickel Co.



Adjustable-pitch propellers for Navy minesweepers and landing craft are special aluminum-bronze castings for erosion and cavitation resistance in high-velocity sea water. Produced by American Manganese Bronze Co., the material contains about 5 per cent nickel, 4 per cent iron and 10 per cent aluminum which produce a yield strength of 60,000 psi and tensile strength of 110,000 psi in the heat-treated state. With the additions, the aluminum bronze is said to have better cavitation resistance than manganese bronze, tin bronze or red brass.

treme cases, the unconsidered, continued use of one material to the exclusion of all others can lead to a completely static situation, in which materials with great potentialities for a particular application are ignored. Milder cases of the same attitude can be noted in many engineering departments.

Two questions might be continually asked about any materials application, "Why are we using this particular material?" and "What material would be better?"—and answers should be actively sought.

On the other hand, the value of working experience with a material cannot be dismissed lightly. Presumably, service failures have been studied (and if they haven't, they should be). The designer has a relatively good idea where the material can and cannot be trusted. The shop has learned how to handle the material; they may even have developed special methods that apply only to the particular material. Thus, there must be good and valid reasons why changing the existing materials specification would result in an improved product.

Intelligent materials evaluation always incorporates the experience and knowledge gained from using a material, both good and bad. Sometimes the unfortunate experiences can be just as valuable as the successful attempts. And experiences of others, as described in articles or papers, often provide valuable sidelights on the material under consideration.

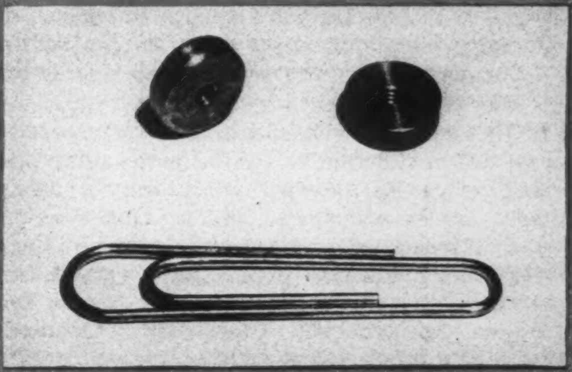
In other words, to rely only on previous experience leads to hidebound dependence on a limited number of materials when others may be infinitely more satisfactory. To attempt the use of a new material without a thorough investigation of its capabilities is equally unwise.

Service Testing: Service testing is one of the preferred methods of evaluating a material, since it involves the testing of a material in the actual component design, subject to the same demands that will be imposed in service. It has one advantage over "experience" as a criterion for materials selection; the assumption that the material will act the same in two different types of design situations is not made. Thus, service testing can often give more accurate information on the capabilities of a material than a limited amount of experience.

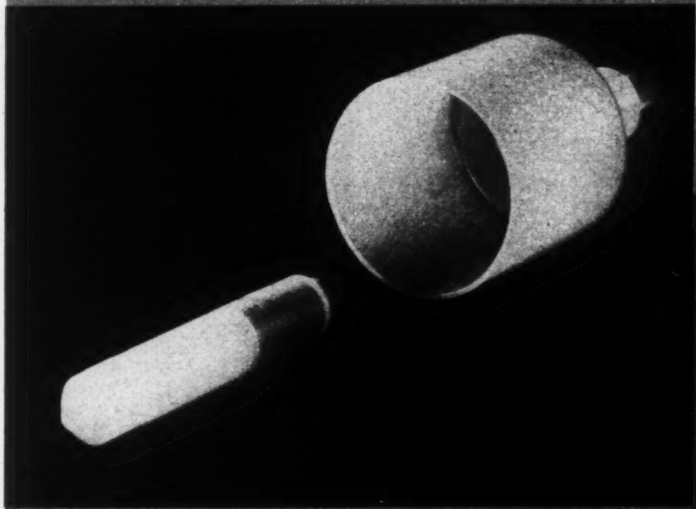
Actual service testing, however, can have several drawbacks. Many service tests involve a "go" or "no-go" procedure—parts either succeed or they fail—and the basic information obtained is thus somewhat limited. If more exact cause-and-effect information is desired, expensive fixtures and instrumentation are needed, which can sometimes run the cost up prohibitively. Thus, depending on the product and type of information desired, service testing may be relatively inexpensive, or may involve a high cost for facilities, manpower and time.

Two other factors can be added to the negative side. One is the relative lack of control of all the variables, which makes the procedure somewhat less exact than laboratory tests. This lack of control may, however, be a blessing in disguise, since unforeseen service

Photo, courtesy P. R. Mallory & Co. Inc.



Used as counterweights in guided missiles, these parts must be very heavy, yet small. A tungsten-copper-nickel alloy, Mallory 1000, provides a specific gravity of 16.8 compared with 11.3 for lead. Additionally, greater strength and a higher melting point are obtained. The counterweights are made by powder metallurgy.



Photo, courtesy Bakelite Corp.

Sanitary and efficient, this valve for a milk-vending machine produced by Food Engineering Corp. is so inexpensive that replacement of the valve is actually cheaper than cleaning it. Both parts are polyethylene, with the solenoid-actuated plunger being molded around an iron core. The plastic is noncontaminating and is unaffected by milk or lactic acid.

factors are included. A factor thought to be relatively insignificant may have a large effect on service performance. The second detraction is that certain types of service tests are applicable only to the particular design, and cannot easily be generalized.

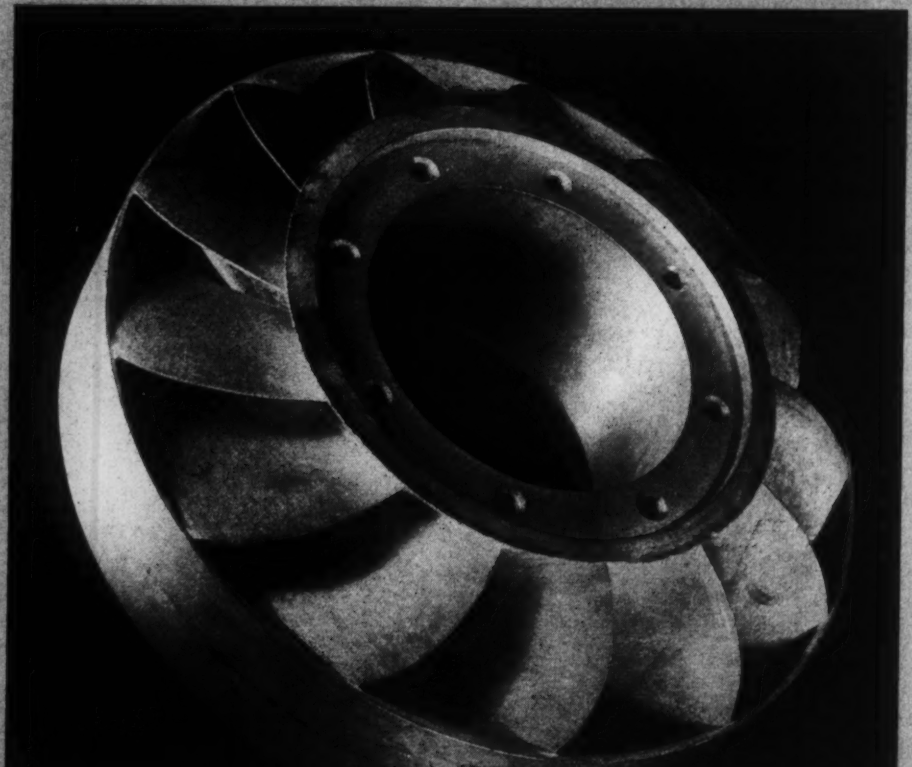
SIMULATED SERVICE TESTING: In simulated testing—testing of the actual component or a generalized shape under conditions approximating those of service—several different varieties can be noted. Certain types, such as accelerated weathering tests or cold-chamber tests, are an attempt to match actual service condition; the part or shape is subjected simultaneously to the combined action of several variables—temperature, humidity, rainfall, air flow, and ice or frost formation, for example. Others, such as acceleration tests of aircraft components or corrosion testing under controlled conditions with a specific chemical, are an attempt to isolate and measure the effect of a particular variable. A distinction between the latter and property tests is often difficult.

Simulated service testing has several advantages over actual service testing. It is usually less expensive, since a part, subassembly or even a model may by studied. The variables that affect a true service test can usually be isolated one by one and individually evaluated. Additionally, data are easy to record and assimilate, since the test is conducted under controlled laboratory conditions.

Significant results can be obtained—but the danger in simulated service testing is that actual service conditions will not be properly duplicated—leading to erroneous assumptions that are not borne out in actual practice. Stress and vibration analysis techniques, essentially simulated tests, are useful and reasonably exact procedures. Attempts to gage the load-carrying capacity of lubricants, however, are examples at the other end of the scale; very few successful tests that correlate well with actual service performance have yet been devised. Wear testing is another area in which it is wise to tread carefully. Too many variables influence wear to permit complete reliance on simulated tests.

The tests, therefore, must be planned by an expert, wily in avoiding the many snares and pitfalls that exist, so that unwarranted assumptions as to suitability of the test will not be made. For example,

Photo, courtesy Aluminum Co. of America



Producibility and strength were requirements for this torque converter reaction member. A furnace-brazed assembly, the White Motor Co. part consists of aluminum permanent-mold cast blades plus forged shells. Dimensional accuracy and smoothness in a thin, sharp-edged blade to eliminate drag and turbulence were thus obtained, along with adequate strength for the application.

"accelerated" tests are valuable because results are obtained in less time than extended service tests. Often they can be used, but sometimes—as in the case of stress-corrosion testing—short-time tests can be misleading.

EVALUATION BY PROPERTIES: Property tests can be considered specialized simulated service tests, in which the shape, form and size of the specimen are controlled, and standardized test conditions are set up to isolate one or a small number of service variables. Thus, standard property tests are frequently one step further from reality than even simulated service tests, since an actual design is not used.

The advantages of property tests are the relative ease of obtaining data, and the fact that common test standards have been set up for the major properties. A wealth of information on standard properties of materials is available, and test properties are obtained by similar laboratory procedures for many materials. Across-the-board evaluation of materials is possible, therefore, even before a tentative design is evolved—but only to the extent that property tests can be considered valid.

The major disadvantage of properties for materials evaluation has been previously mentioned—noncorrespondence with the realities of service. Tensile strength, for example, is often taken broadly to indicate the "strength" of a material. But tensile strength by itself (or even coupled with a ductility indication such as elongation) tells very little about the notch sensitivity of a material, section sizes over which the value may be presumed to hold true, the effect of residual stresses and prior stress history or, more important, the actual strength under combined stresses in service.

WHICH IS BEST?: Obviously, there is no single best approach to evaluation of a material's service characteristics. Any attempt to formulate a "philosophy" of evaluation would probably wind up with the startling fact that the only philosophy involved consists of common-sense application of every particle of knowledge that can be gleaned about the material. Experience is a big factor, not only that of the particular engineering group, but that of technical representatives, metallurgists, chemists and all other outside consultants.

Each of the testing and evaluation methods, however, has a general area of usefulness, although these areas may overlap and are certainly not the same for every product and material. A brief summary of the main features of each might be:

	Property Tests	Simulated Service Tests	Service Tests
1. Relation to actual conditions	Good to poor	Good to poor	Excellent
2. Control of test variables	Excellent	Excellent to fair	Good to poor
3. Relative cost	Generally low	Low to high	Moderate to high
4. Probable design stage	Preliminary	Preliminary to final	Advanced to final

This classification is subject to many individual qualifications, but serves to point out in a broad

Photo, courtesy Kennametal Inc.

Long service life under rigorous impact and wear conditions is the prime requisite in this pulverizing hammer in food-processing machinery. Formerly cast in manganese steel, hammers were lasting for about 100 tons of production. The hammer with a cemented tungsten carbide face has lasted for production of over 2500 tons.

way the utility of each type of test procedure.

In general, service testing is usually considered to be one of the better ways of evaluating a material, since all factors that actually affect the final design are likely to be present. Service testing is often used as a final check of the design after a preliminary production run, since the overall design must be reasonably fixed. In redesigning a component, however, the existing product may be utilized along with the redesigned component as a basis for the service test.

Another area of exceptional utility of service tests is in checking the correlation of property tests or simulated service tests with actual conditions. Often an inexpensive simulated test can be set up in place of a more costly service run.

Unfortunately, one good source of low-cost service data—actual failures—is always available, although not usually utilized to the fullest extent by the engineering department. Parts scrapped by production and failures in the field service can supply valuable information regarding adequacy of both the design and the material. Included are representative material defects, design faults, and production troubles that plague the designer. Rummaging in the scrapheap often pays off in better designs—and there's no charge for an extensive laboratory investigation.

The obvious flow of both is simulated service tests and property tests frequently lack correlation with true service conditions. In the case of properties data, the advantage is the relative standardization of test procedures over a range of materials, and the voluminous data available.

For these reasons, use of property tests can usually be considered as mainly a preliminary or tentative selection method. Properties data can indicate that a certain material is worthy of further investigation, or that another material has very little chance of succeeding in a given application. When the application is critical, or where the most efficient utilization of a material is necessary to obtain lowest possible material cost, properties information by itself is not sufficient. But if extensive investigation of material characteristics is not necessary or economically justified, properties data must be utilized. As indicators, properties stand up rather well, if wisely used.

Using Properties in Design

For efficient utilization of properties data, a clear idea of the fundamental differences between standard engineering "properties" of materials and true service characteristics must be gained.

Basically, properties as measured by standard tests do *not* define inherent characteristics of a material. This fact should be kept in mind constantly, since it will tend to dissipate any settled assumption that a particular characteristic can be shown adequately by properties data.

Tensile strength, for instance, is usually regarded as one of the more accurate test properties, bearing a definite relation to "strength" of a material. Tensile strength figures, usually from handbooks or published data, are widely used as a basis for design. But variations in section size can have extreme effect on tensile strength, sometimes changing the value by as much as 1200 per cent! Thus, tensile strength of tungsten rod is about 50,000 psi; it rises to 250,000 psi in thin wire; and for extremely thin wires, the tensile strength become 700,000 psi. Which is the actual "strength" of the material?

Figures for tensile strength, hardness, elongation, impact strength and other properties can never—strictly speaking—completely give the information desired. There must always be a mental reserve, since "properties" represent, after all, the results of testing material of a *particular* size, shape and condition under a *single* set of controlled influences. Rarely does the property test situation correspond exactly to actual service conditions and the configuration of the designed part. The degree of correspondence that can be assumed is a matter of experience and judgment, and must be evaluated individually from the designer's knowledge of the intended performance of the design under expected service conditions and the applicability of the test.

Properties and Actual Conditions: Despite the limitations previously mentioned, the practical utility of properties data cannot be denied and wide use of this type of information is thoroughly justified by its standardized form and relative availability. Of course, better tests would be desirable; new ones are constantly being devised and inferior ones discarded. Supplementing property test information with actual experience and "horse sense" will always be needed.

The relation between property tests and actual service conditions will be considered in more detail in later articles; however, a broad review of the major points may prove helpful.

STRENGTH: Actual material strength is not a simple property, measured easily by the results of one property test. In service, a material may be called on to resist (1) static loads of constant magnitude and direction, (2) loads varying in magnitude and/or direction, and (3) more intense load peaks of short duration. Property tests have been designed to measure each of these three different loading situations.

Tensile, compressive, torsion, bend (flexure or transverse) and shear tests are essentially static tests, since the attempt is to measure the maximum load that a material can withstand at a relatively slow, constant loading rate. Fatigue or endurance tests fall into the second class, since rotating-beam, tensile (axial), and bending fatigue tests subject the specimen to a variable load, either constant in direction or completely reversed. Impact tests—Charpy, Izod and tensile-impact tests—are basically attempts to determine the effects of sharp load peaks.

The main difficulty in all strength testing is that rarely are actual loading conditions so conveniently classified. The usual service situation is a combination of all three types of loading, possibly with one type predominating. Additionally, the stress pattern and direction of loading within any member will probably be complex, so that the property test cannot usually be considered a complete indication of the material's strength under actual loading conditions. Thus, for a shaft, torsion tests are the most indicative, although the loading may be constant, variable in magnitude, or essentially an impact condition. Axial loads may also be a factor, so the combined loading can become difficult to evaluate properly.

To add to this complexity, prior stress history (which has an effect on strength), notch sensitivity (not measured completely by "impact" tests), and the effects of modifying factors such as temperature and corrosion are not considered by the standard mechanical tests.

STIFFNESS OR ELASTICITY: Measurements of rate of deflection of a machine part or member—modulus of elasticity and Poisson's ratio—are subject to somewhat the same type of criticisms. Modulus of elasticity is conventionally measured in tension (Young's modulus), shear (modulus of rigidity), or compression. Values in shear are lower than those in tension, and compression values may be different.

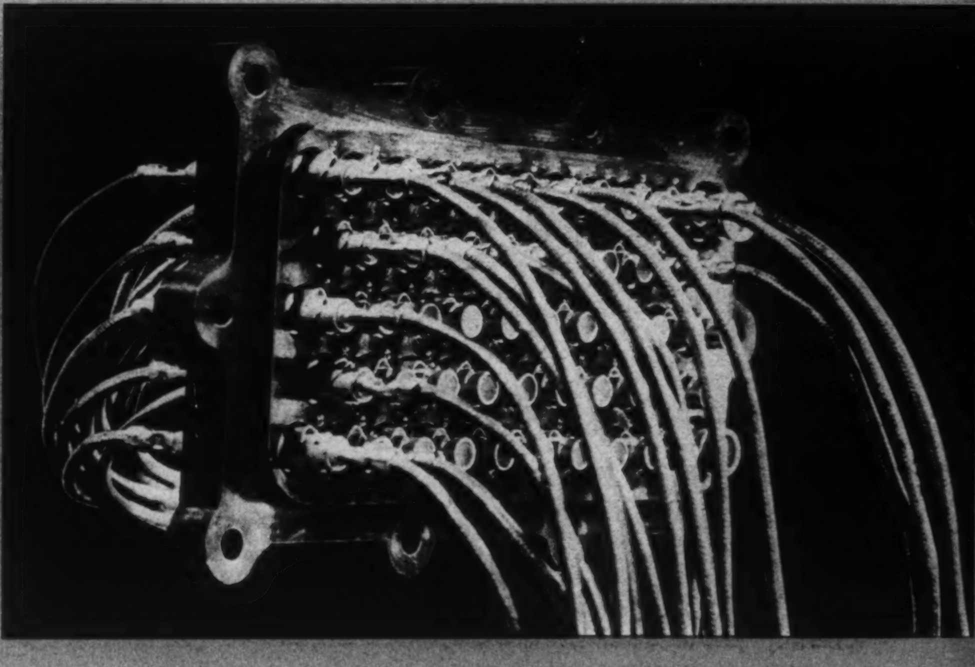
All of these moduli depend on the way the material deforms. By definition, modulus of elasticity applies only within the elastic limit of a material, but many materials exhibit plastic deformation (flow) at the same time. For these, the meaning of modulus elasticity is somewhat vague. Other factors, such as temperature, also have a definite effect.

DUCTILITY: Deformation characteristics in the plastic range of a material, where the material "flows" to conform with stresses, are conventionally gaged by elongation or reduction of area (both in tension), angle of twist at failure (torsion) or deflection at fracture (bending).

The practical usefulness of ductility measurements has been a debatable issue for some time. Some degree of "flow" is certainly necessary to permit parts to adjust themselves to inaccuracies in fit; however, many contend that almost all materials, unless they are glass-brittle, have sufficient ductility for most engineering purposes. Ductility is also taken as an indication of toughness—the "guts" of a material that permit it to withstand shock and impact loading without fracture. But in times past, designers have leaned so heavily upon minimum specification values for elongation or reduction in area that metallurgists have occasionally labelled them "ductility-happy."

Another way in which ductility measurements presently serve is as indicators of formability or drawability. Correlation with actual conditions in this area is very questionable, as will be shown in later articles.

Photo, courtesy Durez Plastics & Chemicals Inc.



Sharply varying pressures and temperatures occur on one face of this electrical disconnect panel, which is mounted in the wall of a pressurized aircraft cabin, while the other side is exposed to relatively constant interior conditions. Molded of electrical type phenolic plastic for Burndy Engineering Co. Inc., the panel material must maintain high dielectric strength and mechanical properties under unfavorable conditions.

HARDNESS: An ephemeral property, "hardness" has never been adequately defined. Hardness might be considered resistance to permanent deformation. In property tests, such as the Brinell, Rockwell or Vickers tests, hardness means resistance to indentation. In practical terminology, hardness may denote resistance to cutting with a tool, resistance to abrasion between two surfaces, or resistance to wear by flow of an abrasive substance.

Actually, each of these involves some combination of strength, resistance to deformation, and what might be called toughness. But hardness is not always the perfect indicator for the characteristics of wear resistance or resistance to indentation and cutting. Rubber can often resist sand-blast abrasion better than steel; here the softer material is better. But hardness generally carries a connotation of wear resistance. One other use to which hardness properties are widely put is as an indicator of tensile strength and condition of metals. Hardness tests are nondestructive and easily made—hence their wide-spread tie-in with heat-treating technology and metallurgical control of material characteristics.

THERMAL CHARACTERISTICS: Temperature has an important effect on all materials and on their characteristics. Form of the material, internal structure, and the effect of external variables such as rate of oxidation are all affected profoundly.

Some of the simpler properties measured are those concerned with temperature alone, such as thermal conductivity, specific heat, coefficient of expansion, and melting point. Most other "property" measurements refer to the effect of temperature on another factor. Thus, a complete tensile test may be run at high or low temperatures. For determining the effect of static loading at elevated temperatures, a creep test may be used, in which the specimen is subjected to a constant load over a relatively long time. Various methods of defining creep include loading to produce a specified creep rate, or stressing to produce rupture within a certain time, both common in this country. Endurance tests may be run at elevated temperature, and the effect of temperature on modulus of elasticity is of importance in some applications.

Thermal tests as a whole have not been well standardized, and the combined effects of temperature and corrosion are pretty much a matter for individual investigation.

CORROSION: Lumped under the general term "corrosion" is resistance to all types of chemical attack. Corrosion may be considered attack by gases, water, salt water, steam, acids, alkalies, organic chemicals, food products, and even the combined effects of rain, wind, sunlight and air—in other words, atmospheric weathering. Similar effects, such as swelling of natural rubber in oil or petroleum, or water absorption by certain plastics, are not "corrosion" in ordinary terminology, but have many of the same practical effects.

Corrosion-test methods suffer under one disadvantage, somewhat common to testing in general; standard procedures applying to all materials do not exist.

Photo, courtesy Synthane Corp.

R-112
R-110
R-113
R-114
R-108
R-102
R-104
R-106
ON
OFF
S-102
S-101
J-101
J-102
C-101
C-102
C-103
C-104
C-105
C-106
E-101

Combinations of several materials are frequently the answer to particular problems. In these "printed" circuits, laminated plastics clad with copper or aluminum foil are etched to provide complex circuits in limited space. A paper-base grade of laminate is used, combining good electrical properties with ability to be blanked and punched easily. The clad laminates also withstand a hot solder test, involving floating foil side down in hot solder at 400 to 450 F for 10 seconds.

Except for certain overall guides which can delineate broad areas of usefulness, individual consideration must be given to each material in the actual conditions under which it will be used. Corrosion tests are, therefore, more like simulated service tests than property tests.

Corrosion can also affect other characteristics—particularly strength. Several more or less standard tests have been evolved for stress-corrosion testing. Corrosion-fatigue, which combines normal fatigue effects with effects of stress raisers caused by pitting, is sometimes an important consideration for which tests have not been so well standardized.

ELECTRICAL PROPERTIES: Electrical characteristics of a material are measured by two broad classes of test—those for nonconductance, and those for conductance or conductivity. Each of the tests is subject to similar qualifications as mechanical tests; inherent inaccuracies are present.

Main tests of dielectric materials are: dielectric constant, which measures "quantity" of electricity charged by a capacitive circuit; dissipation factor, the measurement of the fraction returned to the circuit upon discharge; resistivity, or resistance to current flow under an impressed potential; dielectric strength, the rupture strength of a material in an electrostatic field; and arc resistance, or resistance to the action of an electric spark. Conductivity is usually measured by reference to an international copper standard.

Evaluation of dielectrics must usually be made at equivalent thicknesses, even though the reported property, such as dielectric strength, may be recorded per unit thickness. A ½-inch thick plastic piece, for example, may puncture at 100 kilovolts, indicating that the dielectric strength is 200 volts per mil, whereas the same material in 1/16-inch thickness might fail at 30 kilovolts, with an apparent strength of 480 volts per mil. Care must be exercised, therefore, in evaluating materials by the apparent electrical property.

MISCELLANEOUS CHARACTERISTICS: The group of characteristics and properties outlined is only the beginning of a long list which may have to be evaluated. Wear characteristics have only been touched on; magnetic properties, bearing characteristics, machinability, formability, spring properties, optical properties, vibration-damping characteristics and a host of other special characteristics may be of interest. Each must be evaluated separately, and the designer should understand the advantages and limitations of each property test.

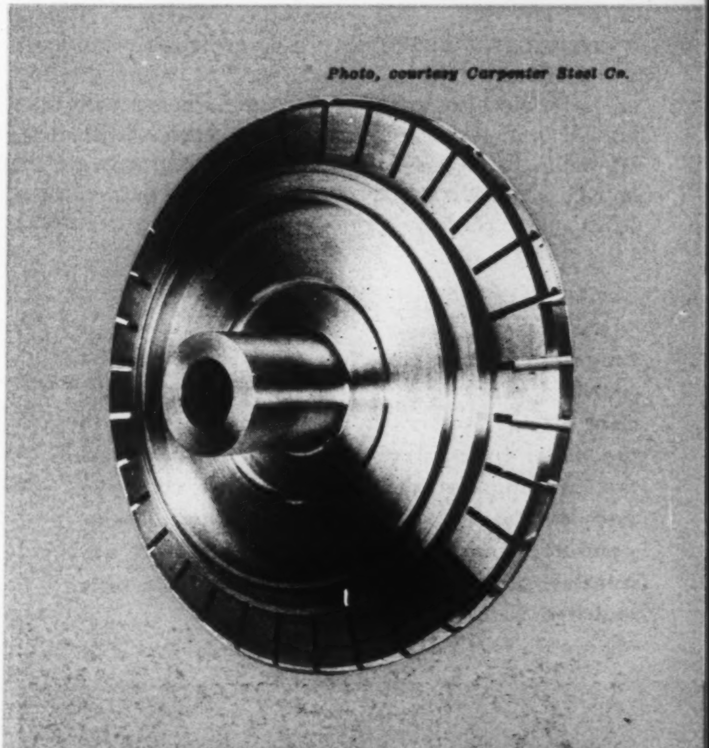
Use of Properties Data: How can property test data be used most efficiently and accurately in design? Three major present-day uses in design can be listed:

1. As service or processing guides and indicators
2. As numerical data in design
3. As specification qualification tests

To a certain extent, end-use of the data determines its applicability, although the restricting factors previously mentioned apply in almost every case.

SERVICE INDICATORS: The use of properties data as service and processing guides has already been touched on. Here, the purpose is to use the information as a means of choosing one or a number of eligible materials for a particular design. The relative reliability of each property test differs; in general, the simpler the test (i.e., the fewer physical characteristics being tested) the more valid.

Impact tests, for instance, are not usually considered as reliable as simple tensile tests in evaluating different materials. Tests for measuring "impact" involve combined tension, compression and shear on the fibers of the test piece, plus the effect of stress con-



Photo, courtesy Carpenter Steel Co.

Providing better properties than are actually necessary often results in higher material cost. This revolving disk for holding cutting knives in a caramel candy wrapping machine requires high strength and resistance to sugar and fruit acids. At the same time, machinability is important because a perfect fit, without any play, is necessary in the knife slots. An 18-8 chrome-nickel stainless steel, the material first used, proved perfect for the job except that corrosion resistance was higher than actually necessary. A change in the material to a type 416 straight chrome stainless (Carpenter No. 5) provided the necessary corrosion resistance, strength and machinability at considerably lower material cost.

centration at the base of the notch, plus a "toss factor" that absorbs energy—important in testing light materials. The tensile test involves only unindirectional loading. The effect of these factors, however, varies with the test, with the material, and with the relation of the two to the actual service condition being indicated.

NUMERICAL DATA: Actually, numerical data for design analysis obtained from mechanical property tests are somewhat limited. The chief mechanical test values so used are tensile or yield strength, and modulus of elasticity. Electric, magnetic, some thermal properties, and physical constants such as weight, density and specific heat find wide utility. But many properties are never used to supply direct quantitative data, among them elongation, fatigue strength and impact strength.

SPECIFICATIONS: Property tests are quite often used as qualification tests in specifications, although this use is subject to some of the same reservations that prevail in the use of properties as service indicators. Minimum values of hardness, elongation, strength or impact strength are frequently made a part of specifications. But the problem is to pick a test that has a high correlation to the actual characteristics desired.

Properties of two materials must sometimes be matched very closely. Glass windows for outdoor electric meters are hermetically bonded to the meter by a glass-to-metal seal to protect the instrument mechanism from dust, corrosion and weathering. To withstand outdoor temperature changes, thermal coefficients of expansion of glass and metal must be carefully matched.

KILOWATT HOURS
GENERAL ELECTRIC
LINE
LOAD

A striking and frequently mentioned case is that of failures that occurred during World War II in welded ships. Tensile tests of the plates that had fractured in service indicated that these plates would meet the specification requirements under which they were purchased. In the usual tensile test, elongation was more than 20 per cent in 8 inches and reduction of area was about 50 per cent. Despite this apparent high ductility, the plates broke with little evidence of plastic deformation; fractures were of the brittle type rather than of the ductile type. One of the conclusions reached by investigators was that the usual tensile test using relatively small specimens was not sufficient; the actual fracture phenomena observed were more like notched specimens broken under tension or bending, particularly at low temperatures. One of the tentative recommendations has been that impact tests be used at the range of temperatures encountered in service. Good correlation was found to exist between low-temperature impact strength and actual performance.

Lacking direct evidence that the particular property correlates well with the service or processing characteristic desired, the designer would do well to steer clear of setting up arbitrary and meaningless tests. The evidence may be in the form of an actual research study, or it may be the result of experience—but in every case the relationship should be clear-cut.

The case against using meaningless properties tests is stated succinctly and forcefully by a quotation from a materials manufacturer, who prefers to remain anonymous: "We feel strongly that designers' fuzzy understanding of [material] technology is costing them (and their suppliers) time, trouble, money and quality. Their greatest need is to appreciate the very limited usefulness of the standard lab tests. They keep writing test values into specifications in the belief that they are specifying serviceability—which they emphatically are not. All they're doing is hamstringing their supplier. We keep telling design people till we're blue in the face that actual service or a special simulated service test is the only way to predict serviceability."

Summary—Properties and Design: Selection of a material at the design stage involves careful balancing of service requirements and characteristics, producibility requirements, and cost. The final criterion of the acceptability of any material is, after all, its performance in actual service. Property test data has the advantage of being readily available and easy to obtain; it disadvantage is possible limited correspondence with actual service conditions. For design purposes, therefore, properties data may be used as service or processing guides, as numerical data for design, or as qualification requirements on specifications. But in each case the designer should use the data with understanding of inherent limitations.

CRITICAL DESIGN FACTORS FOR high-strength steel

Use of standard materials at increased strength levels offers a practical approach to the problems of weight and space conservation encountered today. This article presents a clear-cut analysis of typical design and producibility considerations involved.

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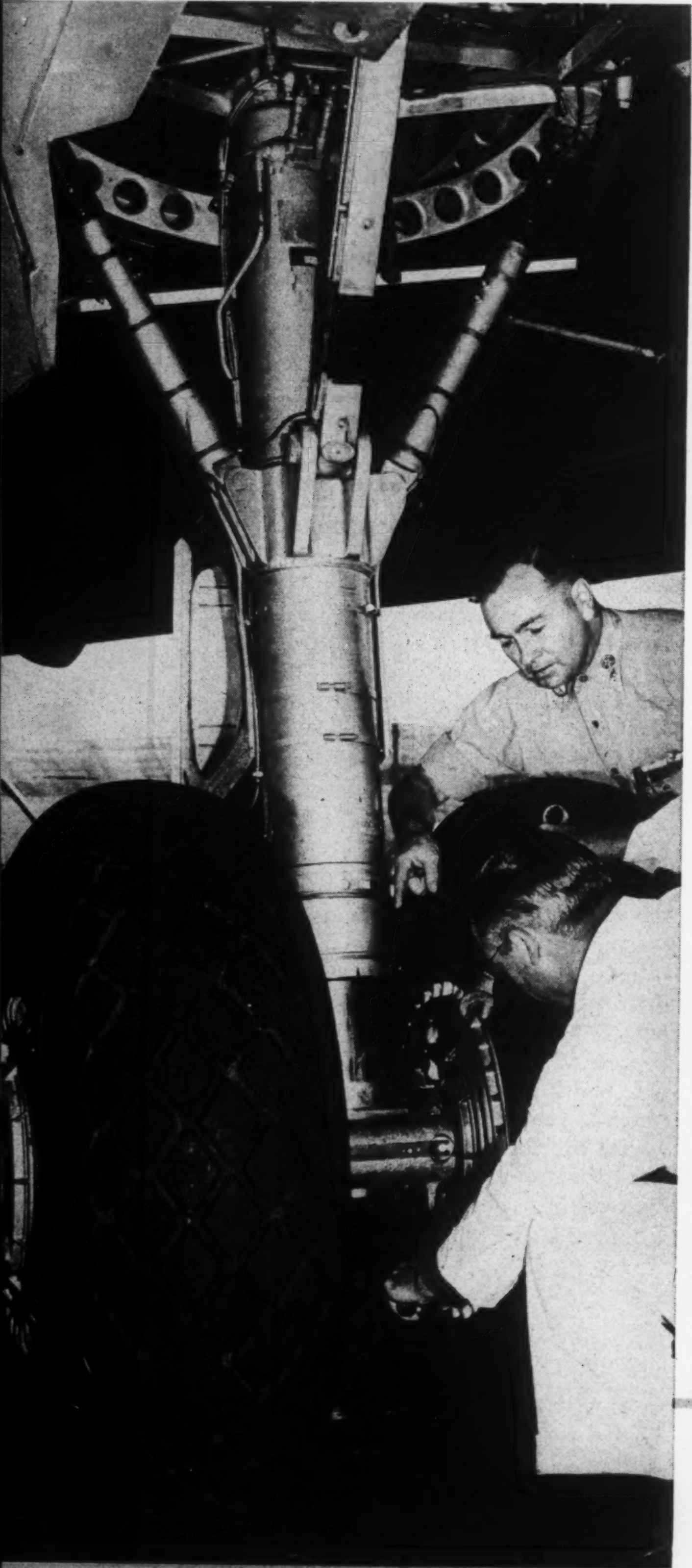
TRENDS toward increased load carrying capacity and higher power output continually impose more severe stresses on components. Under these conditions, standard materials at currently accepted strength levels can be utilized by enlarging cross-sectional dimensions. However, such practice is often inconsistent with good design because of the weight penalty imposed. The increasing importance today of weight saving makes the application of alloys with an improved strength-weight ratio desirable provided other properties are acceptable and production costs are not prohibitive.

To meet these higher loads, the use of heat-treatable steels at a higher strength level than heretofore practiced is attractive from the viewpoint of structural properties and cost. SAE 4340 steel, for example, heat-treated to a 260-280,000 psi tensile range, offers an excellent solution to this design problem. By raising the design level to this minimum, a weight saving of 23 per cent over the conventional 200,000 psi limit can be realized. Comparison of various construction materials, as shown in TABLE 1, reveals the advantageous strength-weight ratio of the high heat-treat steel.

Naturally, one may ask why high strength steels such as 4340 have not been utilized at a higher strength level prior to this time. Certainly, 4340 has been used extensively at a strength level considerably lower than it is capable of developing. Failure to exploit fully the strength available in deep-hardening alloy steels has been due principally to the fact that, as the tensile strength is increased above 200,000 psi, the notch sensitivity reportedly increases and the ductility is lowered. In addition, there has been a general lack of adequate data on structural and fatigue properties at the high strength range. These factors, coupled with increased manufacturing costs involved in the production of high strength parts, have kept design ranges to more modest values. However, with continuing increased demands on structural components, the advantages of high-strength steel should not be overlooked. By proper design and strict manufacturing control, the objectionable features at the high strength level can be overcome.

General Design Considerations

Proper design, manufacturing control and inspection are critical factors involved in the successful usage of steel in the 260-280,000 psi tensile range or any other range. As stress raisers are objectionable in all forms, a minimum relief radius of 0.100-inch should be specified on highly stressed parts; sharp angles and corners are to be avoided; and transitions from thick to thin sections should be gradual. Surface finish requirements must be maintained rigidly, and parts with objectionable tool marks, scratches or nicks should be scrapped or reworked. Raw stock



Extreme loads coupled with rigid weight and space restrictions dictate the application of high-strength alloy steels in this main landing gear assembly of the Lockheed Super-Constellation.

size is so specified on drawings as to permit removal of all decarburization on the finish machined part. Forgings, normally possessing some decarburization, are peened to an intensity of 0.008 to 0.012 *A* with 0.019 to 0.028-inch diameter shot. Heat treatment must be so conducted as to yield the minimum retained austenite with an optimum tensile-yield ratio and the highest level of ductility. Improved welding techniques must be used to provide sound welds. Grinding and machining must produce minimum residual stress, and parts must be stress relieved after grinding. Relief of hydrogen embrittlement after cleaning, pickling, plating and phosphatizing is mandatory. Special handling of parts in transit is required to preclude nicking and scratching, and inspection methods must be extremely thorough to guarantee compliance with all processing requirements.

Mechanical Properties: Three specifications are used at Lockheed Aircraft Corp. for procurement of 4340 steel, depending upon the shape of the products:

Specification	Material
MIL-S-5000	Bar and reforging stock
MIL-S-5000, MIL-F-7190	Forgings
AMS 6415	Mechanical tubing

These specifications assure a certain minimum hardenability, steel cleanliness, grain size and chemistry limits. The variation in properties of hardened material from heat to heat when purchased to these specifications may be appreciable, even though the raw material is closely controlled.

The extent of this variation is indicated in *Fig.* 1, which summarizes the results of tests performed on several heats of 4340, covering the full range of hardenability permitted by specifications. An analysis of the graph discloses that at a given draw temperature, tensile strengths of the various heats may vary as much as 30,000 psi. The yield strength exhibits a uniformly wide spread of approximately 25,000 psi from heat to heat, whereas per cent elongation and reduction of area are more uniform.

For an ultimate tensile of 260,000 psi, the yield strength may range from 220-238,000 psi. The drop in tensile-yield ratio for draw temperatures of 500 F and below probably is caused by retained austenite. It is well known that small percentages of retained

Table 1—Basic Properties of Engineering Materials

Material	Tensile Strength (psi)	Yield Strength (psi)	Elongation (% in 2 in.)	Weight (lb/cu. in.)	Strength/ Weight Ratio*
75S-T6 Aluminum alloy bar	77,000	66,000	6	0.101	1.00
ZK 60A-T5 Magnesium extrusion	45,000	36,000	4	0.0652	0.89
4340 Steel (Conventional heat treat)	200,000	165,000	10	0.283	0.93
4340 Steel (high heat treat)	260,000	220,000	8	0.283	1.20

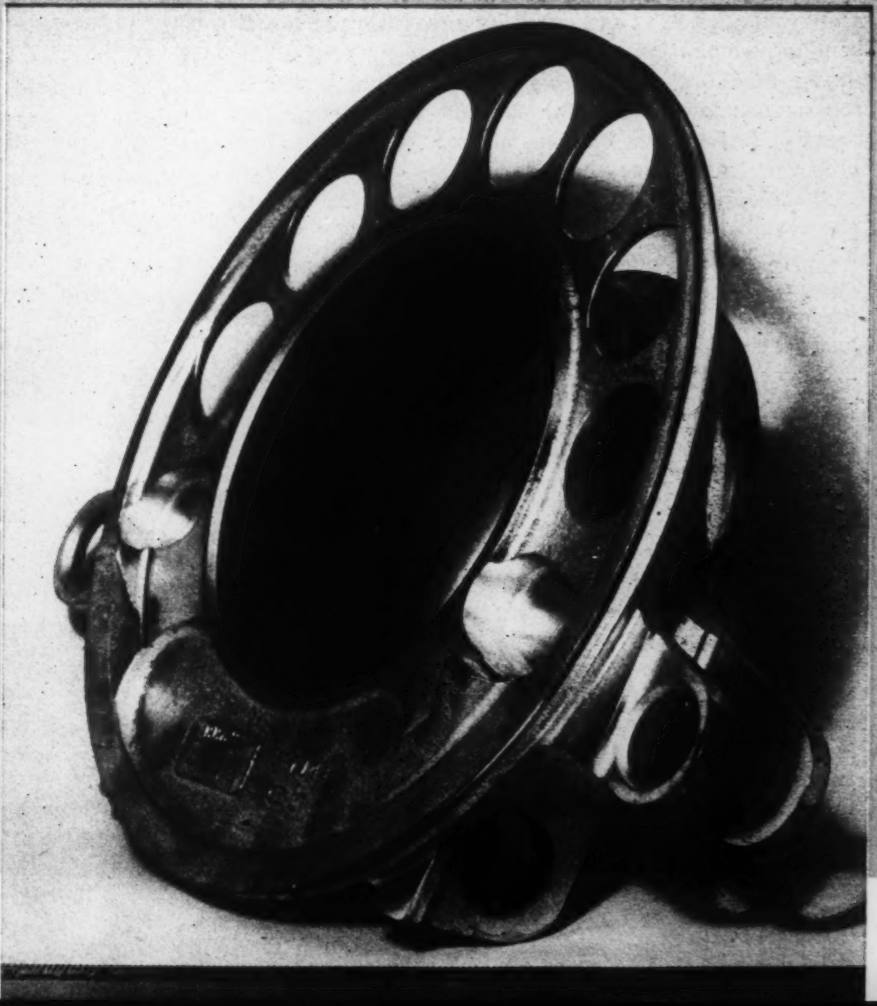
*Based on 75S-T6 aluminum alloy bar=1.00

austenite lower the yield markedly without appreciably altering the ultimate tensile strength. Ductility, as measured by reduction of area and elongation, is very good considering the high strength level. Tensile coupons tested in the high strength range all showed pronounced necking down and the fibrous type of fracture characteristic of ductile material. *Fig.* 2 shows a typical test specimen at approximately 280,000 psi tensile strength.

Impact Properties: As the tensile strength of heat-treated steels is increased, notch impact properties as measured by Izod, Charpy, or similar tests are lowered. Low impact properties have been properly interpreted as meaning that a material lacks ductility, or "toughness," and that this embrittled condition could result in sudden service failure by fracture due to the inability of a part to withstand suddenly applied loads, or even nominal static loads applied at areas of high stress concentration. The belief that lowered impact properties detract from structural integrity has been one of the chief barriers to full utilization of the latent tensile strength in some of our deep-hardening steels. This problem has to be considered when the decision to design at the 260-280,000 psi level is made. A successful solution has been developed essentially along these lines:

1. Adoption of a heat treatment schedule which, in extensive testing, resulted in the highest and most consistent Charpy (notched) impact and tensile (unnotched) impact properties possible, considering the high tensile strength level.
2. Change of design and production methods, wherever necessary, to preclude any serious stress raisers or areas of high residual stress in final parts.
3. Reanalysis of notch and tensile impact data at the high strength level in an effort to determine the precise significance of these properties and their correlation with actual service performance.

A considerable amount of impact testing, including V notch Charpy, V notch Izod, keyhole Charpy and tensile impact has been conducted by Lockheed on heat treated 4340, employing tempering temperatures from 200 to 1200 F. In general, results are in good agreement with previously reported values. Some of these data are shown graphically in *Fig.* 3. Charpy V notch and tensile (unnotched) impact values, tested at room temperature (+75 F) and −70 F are plotted as a function of tempering temperature. The tempering temperatures of 350 to 700 F represent tensile strengths from approximately 315,000 to 220,000 psi. As is usual with most low alloy steels, a shallow minimum, or "valley" in the Charpy vs. tempering temperature curve occurs at approximately 600 F (parts



Aircraft nose landing gear steering collar illustrates the shape complexities which can be achieved with high-strength SAE 4340 through careful design and heat treatment.

at the 260-280,000 psi level are tempered at 400-500 F). Tensile impact energy, on the other hand, is more directly related to static tensile properties over the tempering range covered in *Fig.* 3, and increases as draw temperatures are lowered. Impact values at −70 F are not significantly different from those at room temperature. Ductile fractures were obtained at both testing temperatures.

The interpretation and application of such quantitative impact data are difficult. Opinion is divided as to the values of impact testing when trying to translate laboratory behavior of specimens of arbitrary geometry to probable service performance of actual parts. Consequently, a careful study was made of the practical significance of impact tests. Most investigators seem to agree on these points:

1. Impact values do not represent a fundamental property of the material being tested but are more a function of specimen geometry and testing conditions.
2. Impact values cannot be used in design since behavior under laboratory conditions bears little if any correlation to service conditions.
3. The principal use of impact data is for comparison with the same material in different conditions, or similar material in the same condition, which has a service history.

In the latter connection, Lockheed has for some time tempered oil-quenched 4340 at 800 F for parts similar, and in some cases almost identical, to those proposed for the 260-280,000 psi range. "Ductility" and "toughness", as measured by notch impact, notch bending, elongation, and reduction of area of 4340 drawn at 800 F are not significantly higher, and in some cases lower, than for the 400-500 F tempering range. Performance of these aircraft components has been very satisfactory.

After careful consideration of all of these factors the conclusion reached was that rejection of the new high strength design range on the basis of relatively low impact properties is not justified when, as is the present case, the potential difficulties are recognized and provided for by improved design, heat treatment, and processing.

Fatigue Properties: Although the design of aircraft structures is nearly always based on static strength properties, fatigue testing is very valuable in forecasting the probable behavior of parts under dynamic loading conditions in service. Fatigue data on a new material are not used directly in design, but comparisons can be made with other materials with which considerable service history is available.

To establish the fatigue properties of 4340 steel at the 280,000 psi strength level, S-N curves were determined under completely reversed loading, tests being conducted in a 10,000-pound capacity vibrating beam machine. To determine the variation in the ratio of fatigue strength to ultimate strength, S-N curves were also defined for the same steel at other heat treatment levels down to 190,000 psi. Notched specimens having elastic stress concentration factors of 1.2, 1.6, and 3.0 were used at each strength level investigated to compare notch sensitivity of the highly heat-treated steel with that of normal design levels. By extrapolation, the S-N curve for a stress factor of 1.0 (smooth surface) was also established. Some tests were also run on specimens with decarburized surfaces. All of the results of this program cannot be presented graphically here, but are summarized as follows:

1. Notch fatigue strength of 4340 increased as the ultimate tensile strength increased from 190,000 psi to 280,000 psi; *Fig.* 4 is illustrative of the type of data obtained. The family of S-N curves for an elastic stress concentration factor of 1.6, shows that for all cycle ranges the fatigue strength is higher at the 280,000 level than at lower strength ranges. This same relationship held in all cases, except for the very low cycle range of the curve for the high stress concentration factor of 3.0, where the fatigue strength remained essentially constant as the tensile strength

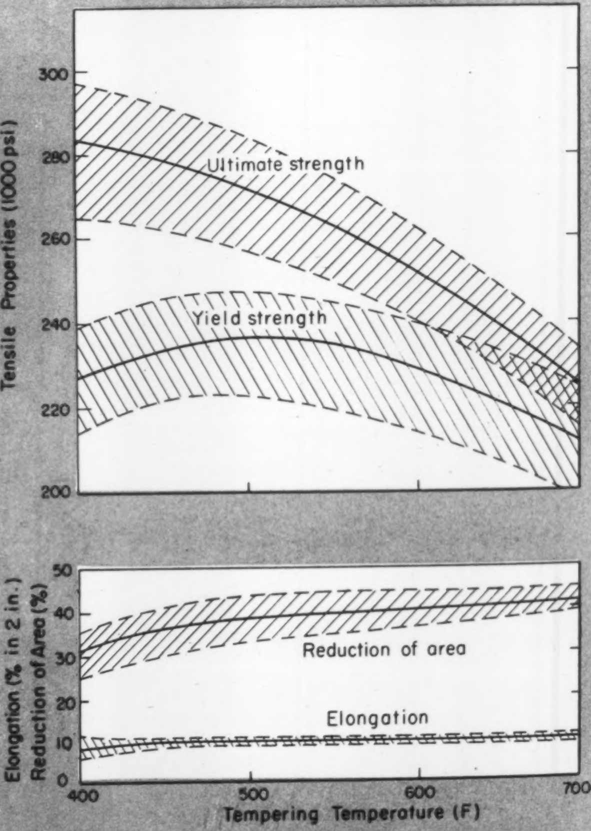


Fig. 1—Properties of heat-treated SAE 4340 steel. Solid lines represent normal expectancy and dotted lines represent range of values determined by research at high strength level

was increased to the higher levels.

2. Except in the very low cycle range (normally above design limit stress), the ratio of fatigue strength to ultimate strength remained practically constant, and the steel showed a decreasing sensitivity to notches, as the tensile strength was raised from 190,000 progressively to 280,000 psi. This decrease in notch sensitivity is in direct contrast with structural aluminum alloys, where increases in the tensile strength have been associated with increased notch sensitivity.

3. Decarburization has little effect on fatigue life of a part at the 200,000 psi tensile level. However, in the 260-280,000 psi range, a decarburized surface reduces the fatigue life markedly, behaving much like a notch in the steel. To preclude the effects of decarburization, machining operations are so sequenced as to permit removal of undesirable material.

Heat Treatment

Hardening: One of the prime requisites of an engineering process is reproducibility of the design properties. For high-strength steels the method of heat treatment must be capable of producing consistently the required tensile strength along with optimum yield strength, reduction of area, elongation and impact properties. The process must guarantee an acceptable tensile-yield relationship and must apply equally to thick and thin sections. Heating must keep decarburization at an absolute minimum since removal of decarburization after hardening is an expensive machining operation. After extensive tests, a standard heat treating cycle has been adopted for all parts.

The first phase of heat treatment includes normalizing of the material at 1600 ± 25 F to produce a homogeneous structure with complete solution of carbides. Heating and soaking times are somewhat longer than ordinarily performed to afford more complete solution of the hardening agents. Normalizing is beneficial in providing parts with a common thermal history for subsequent hardening; tests have shown an improvement in yield strength, ductility and notch impact properties due to normalizing.

Austenitizing is accomplished by heating to 1500 ± 25 F in accordance with the following approximate schedule:

Largest Section Thickness (in.)	Heating Time (hours)	Holding Time (hours)
Over ¼ and including 1	¾	1
Over 1 and including 2	1¼	2

The lower temperature was selected to keep to a minimum the retained austenite upon quenching in oil.

Tempering is performed for 4 hours per inch of cross-section, with a four hour minimum, in accordance with Table 2. The long times are necessary to assure a stable microstructure; tests have indicated that shorter times may result in an appreciable variation in properties, and that parts lose strength as a result of subsequent baking operations after plating, grinding, etc. The effects of tempering temperatures and time on mechanical properties for one of the

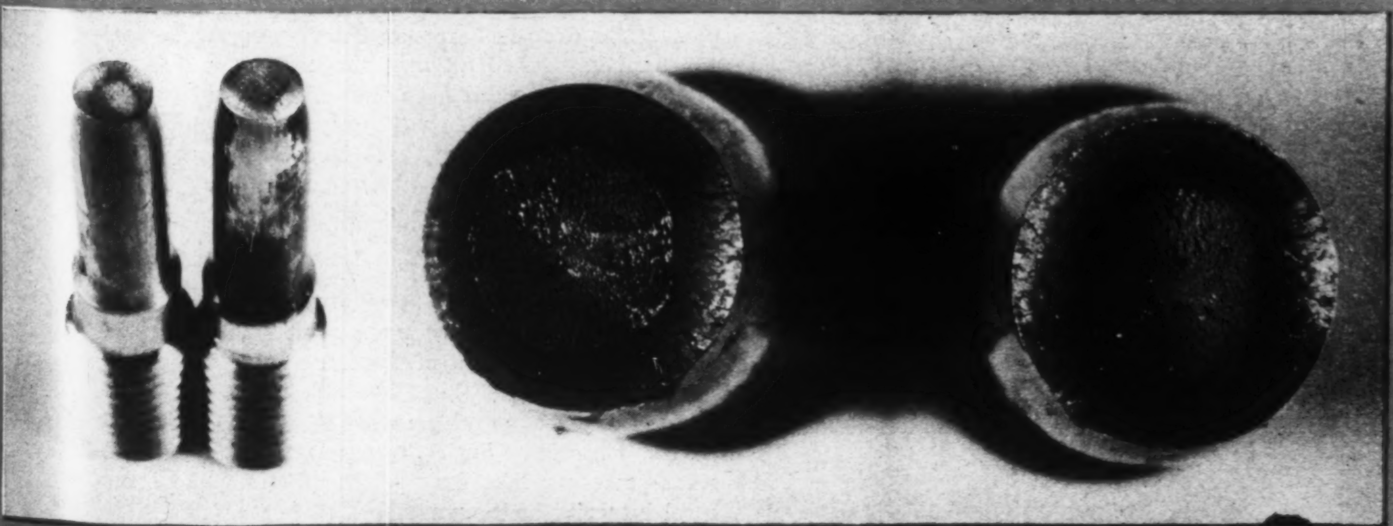


Fig. 2—Typical static tensile specimen of SAE 4340 steel, heat treated to 260-280,000 psi strength level. "Cup and cone" fracture, pronounced necking down and fibrous appearance indicate ductility of the material

heats investigated are indicated in *Fig.* 5.

As a final thermal operation, all parts are heated at 250 ± 10 F for 24 hours to stabilize any residual austenite. The process is required to assure dimensional stability plus freedom from residual stresses that would accrue from possible austenite to martensite conversion in service. No subsequent reheating beyond the limiting temperature of 250 F is permissible on the parts.

Hardness-Tensile Conversion: To determine whether parts are heat treated to the 260-280,000 psi tensile range poses a major problem. Use of tensile test coupons with treated parts does not provide an accurate measure of compliance and the cost of testing would be prohibitive. A nondestructive method for evaluating mechanical properties, such as hardness testing, is by far preferable from an economy standpoint. A survey of graphs and charts on hardness-tensile correlation indicates a certain divergence of values, particularly at the higher strength levels. The necessity for establishing a valid hardness-tensile relationship at the high strength level is very apparent. By conducting a statistical study on specimens used to establish the optimum heat treating procedure and an analysis of similar data from other companies investigating the high strength level, TABLE 3 was compiled.

Adequate relief radii, avoidance of sharp angles and corners and gradual section transitions are essential design considerations in the application of high heat-treat SAE 4340 steel to parts such as this nose landing gear piston.

Inspection techniques also play a significant role in determining whether parts are at the 260-280,000 psi range. The very narrow Rockwell C band which constitutes the acceptance limit for the material dictates the use of extreme precautions in determining part hardness. Accuracy of the testing machine, variation of test block hardness and operator efficiency are all important considerations in correct hardness determinations.

Size Limitation: The excellent hardenability of 4340 steel allows the use of fairly heavy cross sections with uniform properties. Size limits of the material for the 200,000 psi minimum have been established; however, because of the higher tensile strength design range, it was necessary to redetermine the maximum size of material that would through-harden to 260,000 psi minimum. Obviously, this was to be a smaller cross-section than used heretofore.

Maximum sizes that can be hardened to 260,000 psi minimum were derived from a study of hardenability curves, which show the hardness of "as quenched" steel, and from "tempered hardenability" curves which present the drop in hardness after tempering at various temperatures. Different shapes cool at different rates during quenching, so that the maximum cross section that will harden uniformly also depends upon configuration. Based on these factors, the maximum sizes of various shapes which can be heat treated throughout to a minimum of 260,000 psi tensile are indicated in TABLE 4.

Warpage Control and Straightening: Heat treatment, particularly of the more complex shapes, produces a certain amount of distortion. Unfortunately, the straightening of high heat treated steels is restricted to a considerable extent by the high strength of the material. Such processing also induces residual stresses that may seriously affect the structural integrity of the parts.

Aside from structural considerations, warpage control and straightening are vital factors in the production of parts at minimum cost, as any machining performed after hardening is an expensive operation. A straight, nondeformed part permits minimum allowance for removal of stock for compliance with di-

Table 2—Drawing Temperatures

Hardness (Rockwell C)	Drawing Temperature* (F)
53, 54, 55 or 56	400
57 or 58	450
59 or above	500

*Tempering at less than 400 F is not permitted

Table 3—Hardness-Tensile Relationships

Hardness (Rockwell C)	Ultimate Tensile Strength (psi)
48	243,000
49	251,000
50	260,000
51	268,000
52	276,000
53	284,000
54	293,000
55	302,000
56	310,000

Table 4—Size Limitations for Through-Hardening

Shape	Maximum Section (in.)
Bar, round	2
Bar, square	2
Bar, rectangle (1:2)	1½
Plate	1½
Tubing	¾*

*Dimension applied to wall thickness. For open tubes that will be quenched on the inside during heat treatment, this wall thickness dimension may be doubled.

mensional tolerances.

To limit distortion to a minimum, heat treatment of long, thin parts is accomplished in vertical furnaces. Such parts and others of complex shape are so racked and suspended in furnaces as to bend or distort the very least at heat treat temperatures. Parts in which ratio of length to cross section is large are quenched vertically in the oil bath.

Straightening of heat-treated parts is permissible provided no heat is applied. Should straightening cause any noticeable deformation, such as kinks or bulges, the parts are rejected. Where straightening is accomplished successfully, parts are stress relieved by heating to 375 ± 25 F, holding for a minimum of 4 hours and cooling in air. Next operation is shot peening to an intensity of 0.008-0.012 *A* (Almen No. 2 Gage) with 0.019 to 0.028 inch diameter shot.

Producibility

Machining—Metal removal, insofar as possible, is performed on the steel in the annealed condition. However, due allowance must be made for distortion of the large parts in heat treatment, making it necessary to finish machine in the hardened condition. Decarburization is machined off or shot peened. Machining to produce satisfactory surface finish with maximum tool life can be accomplished only when the fixture, part, and tool are held rigidly. Cost is appreciably increased because of short tool life. Investigation of machining operations at the high strength level show the following to be true:

LATHE OPERATIONS—Turning is accomplished successfully with carbide tools at 100 sfm or over, feed of 0.002 inch/revolution and depth of cut under 0.060 inch. Boring in the hardened steel is also feasible with the carbide tools at the same feeds and speeds as for turning but with a depth-diameter ratio of 3:1 maximum. Thread cutting with single point carbide tools provides a good surface finish at high cutting rates, but bits tend to chip. Center drilling, with pilot drill diameter a minimum of ⅛ inch, is possible with high speed steel.

MILLING—Flycutting with carbide tipped cutters provides a good surface finish provided cutter head is rigid. Carbide tipped slitting cutters are unsatis-

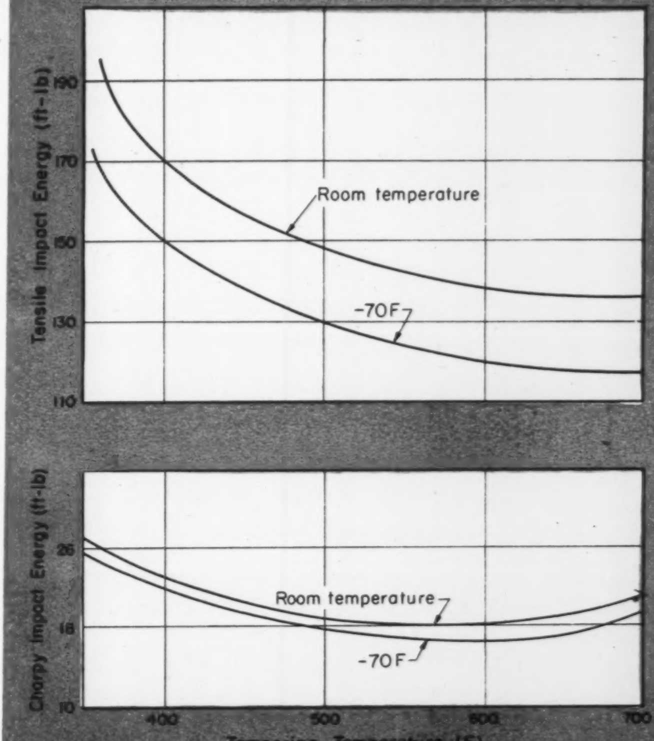


Fig. 3—Tensile impact and Charpy V notch (modified specimen) properties of SAE 4340 at room temperature and −70 F as a function of tempering temperature

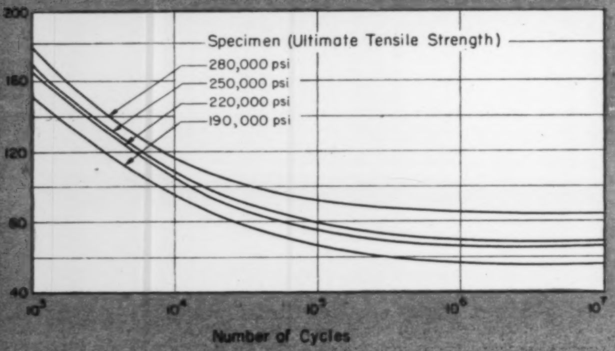


Fig. 4—S-N curves for SAE 4340 steel at various strength levels, determined under completely reversed loading for specimens having an elastic stress concentration factor of 1.6

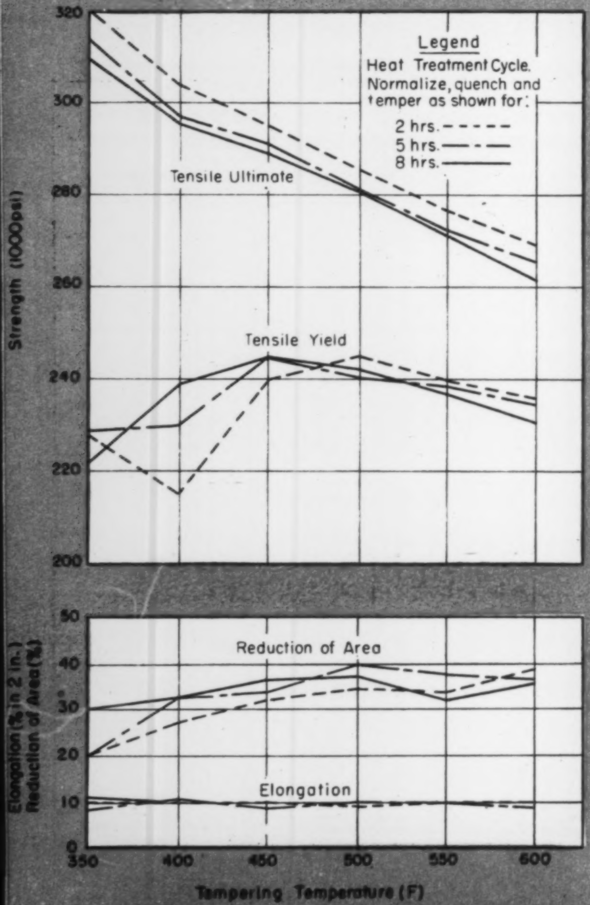


Fig. 5—Tensile properties of SAE 4340 steel, as influenced by tempering temperature and time

factory for cutting because of poor tool life. End milling is accomplished with carbide tipped cutters. Side and straddle milling may also be performed.

DRILLING: Holes cannot be drilled but can be reamed to size with high speed steel drills or reamers. Holes cannot be drifted by reaming with aid of bushings. Threads which were tapped undersize before heat treatment can be cleaned up with high speed steel taps. Solid carbide drills can be used to produce a satisfactory hole, although sharpening of drill is required after approximately one diameter of depth. Consequently, drilling must be performed prior to hardening.

THREAD CUTTING: Tests have shown that both external and large internal diameter continuous threads can be cut in the hardened steel. However, interrupted threads cannot be cut successfully after heat treatment.

GRINDING: Grinding of hardened steel parts is one of the common methods for attaining finished dimensions. However, for high-strength steels, the process requires extremely close control of variables to prevent cracking during grinding and the build-up of residual surface tensile stresses in the completed parts which could cause cracking in service. Residual tensile stresses unduly affect serviceability, while scrappage increases the cost of the parts markedly. Grinding should be permitted only when specifically authorized on the engineering drawing. To preclude the possibilities of any part failures from this process, all components with ground surfaces are stress relieved at 375 F for 4 hours immediately after grinding. Parts can then be magnetically inspected 100 per cent for cracks, followed by shot peening.

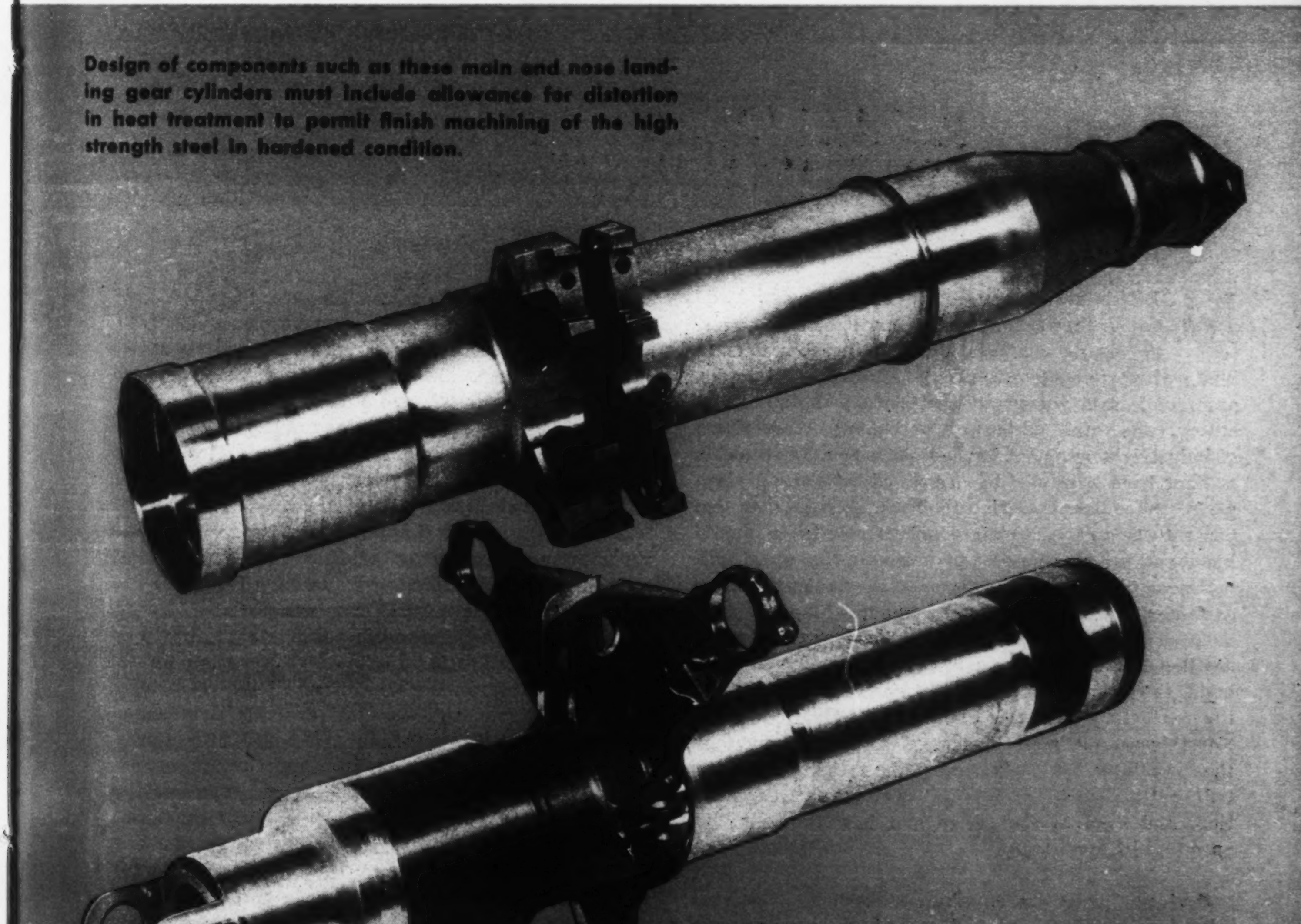
Peening produces compressive surface stresses of mean value equal to 1/3 of the nominal yield stress. Thus, the fatigue strength is markedly improved by shot peening. Where an improved surface finish is necessary or close tolerances must be maintained, peening is followed by honing.

Welding: Strict control over flash and pressure welding must be maintained. Because the effect of inclusions and other defects on high heat-treated steel parts is more adverse than on parts in the lower strength level, an inert atmosphere should be used in all flashwelding because of its tendency to lessen total inclusion count. Secondly, tests to date indicate that the machine's electrical and mechanical settings are more exacting in adjustment and reproducibility requirements.

Finishing: All high heat treat parts in some stage of processing are subjected to cleaning. Where organic cleaners are applied, no harmful effect on structural properties of the steel is manifest. Pickling and cathodic electrolytic cleaning methods invariably induce a pronounced hydrogen embrittlement of the parts. If parts so cleaned were placed in service without proper baking, every likelihood exists for failure in service. Pickled or electrolytically cleaned parts are baked at 375 ± 25 F for 4 hours immediately after cleaning. This is applicable to materials that are not plated or phosphatized subsequent to cleaning. Tests have indicated cathodic cleaning is particularly offensive from the hydrogen embrittlement standpoint. Thus, for all high heat-treated steels, anodic electrolytic cleaning is preferred. Most of the high strength steel parts will require cadmium or chromium plating. Plating produces hydrogen embrittlement of steel much as pickling does, with a very detrimental effect on properties. This effect becomes more severe as the strength level increases. All high strength parts are thus baked for 8 hours at 375 ± 25 F immediately after electroplating to restore the mechanical properties. Somewhat allied to plating from a hydrogen embrittlement standpoint, but with lesser effect, is the phosphatizing process. All parts thus treated also undergo a bake at 375 ± 25 F for 4 hours.

Summary: Present experience with high heat-treated steel shows that a considerable weight savings can be achieved without any capital expenditures on manufacturing equipment or vast outlays for development of new alloys. The usage of steel at the 260-280,000 psi level in aircraft requires only more meticulous processing and more rigid inspection. Because of the tremendous advantages which are realized by fully utilizing the strength of steel, the promise for an appreciable upsurge in the application of 4340 at the 260-280,000 psi level is bright indeed.

This article is based on the investigations carried out cooperatively between the Engineering Research Laboratory and the Production Engineering Department at Lockheed. The comments and suggestions of Messrs. Paul Mozley and George Wald resulting from their review of the article are gratefully acknowledged.



Design of components such as these main and nose landing gear cylinders must include allowance for distortion in heat treatment to permit finish machining of the high strength steel in hardened condition.

SCOTCH CALK
3M BODY CAULKING

sealers

AS ENGINEERING MATERIALS

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MODERN sealers are giving designers new ideas for sealing seams, filling holes, closing pores, smoothing surfaces and filleting joints in all kinds of parts and assemblies. Airplane fuel tanks, automobile rain gutters, boat decks and hulls, refrigerator coils, tank periscopes and many other pieces of industrial equipment have either been made possible or have been improved by proper use of today's high-performance sealers, *Fig.* 1. They comprise an important class of materials which the designer should know and use as a part of his regular "bag of tricks".

Frequently sealers can be used to great advantage as faster, lower cost means of accomplishing the same purpose as welding, brazing, soldering, gasketing or costlier design. Because sealers on the job are usually inside, efficiently doing their work between or behind the parts they seal, few are aware of their presence. For this reason, many designers completely overlook the possibility of their use. This article, therefore, will outline their properties, performance, application, and uses to see where and how they may be specified to advantage.

Sealers: There is a fine line of distinction between adhesives, coatings and sealers and the same product often can and does serve more than one of these functions at the same time. In the broad sense, we shall consider that:

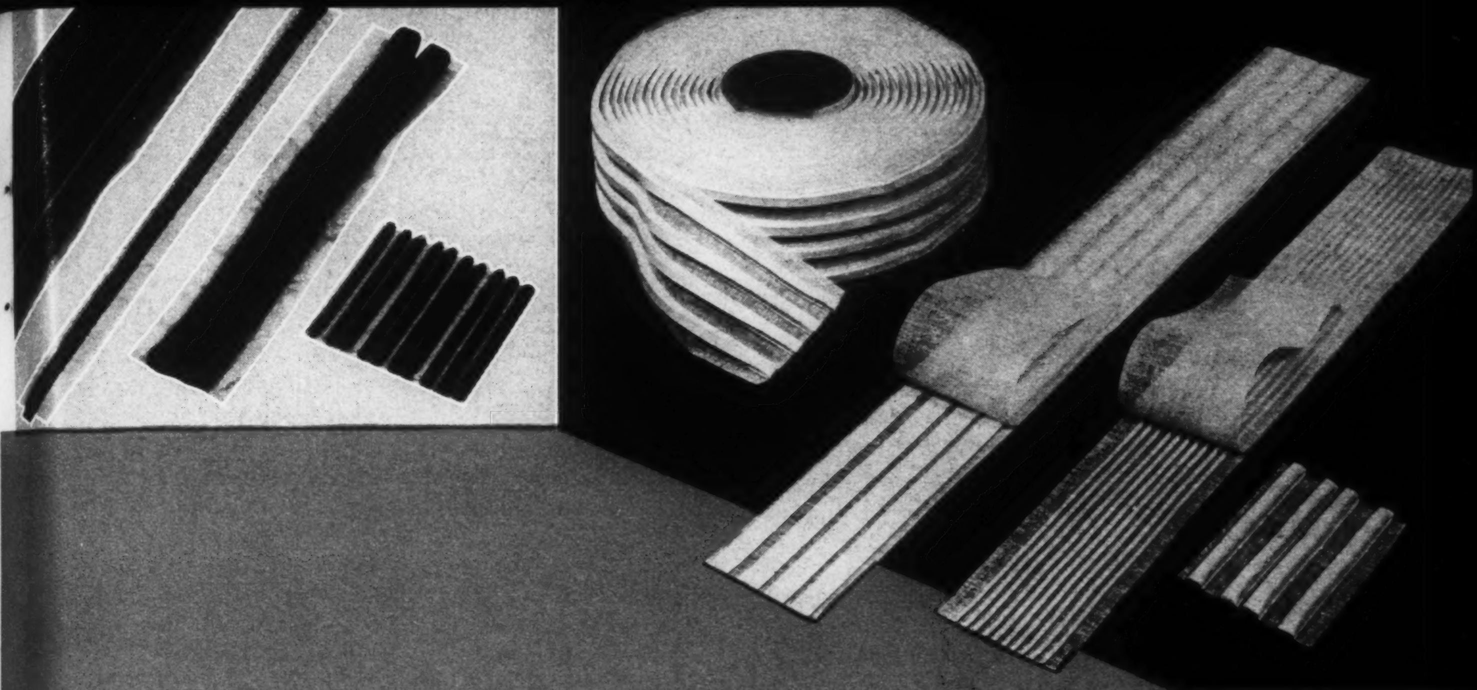
1. Adhesives join surfaces.
2. Coatings cover surfaces.
3. Sealers bridge surfaces.

These oversimplified definitions are intended only to distinguish the main topic under discussion from its equally interesting close relatives. Sealers, as we shall use the term, are materials whose chief purpose is to render a unit or some portion of it tight enough to contain, confine or exclude liquids, gases or dust. In addition, sealers are often employed in the filleting or fairing of surface contours.

The physical forms of sealers range from water-thin liquids to fairly hard solids. Compositions are varied also, though most of those to be considered are compounded rubbers or resins. They can be formulated to meet almost any combination of service conditions. Application is possible by many types of standard equipment or by a wide variety of ingenious devices to meet specialized needs. Their uses are so numerous that we can describe only a few to illustrate their usefulness.

Basic Types: Perhaps the most practical way to classify sealers is to consider how they are transformed from the bulk packaged state into the final useful condition required for the job. Products fall into three general categories:

PLIABLE SEALERS: These are the familiar putty-like material, typified by regular glazing putty and calking compound. Their main feature is pliability. Some of the ordinary ones contain oils which oxidize upon exposure to air, forming a tough skin on the surface or progressively hardening throughout. Newer types either contain nonoxidizing oils or are not based



Today, sealers can perform a multitude of services in design and, in addition, often effect useful savings in cost. Modern sealers available are discussed in this article along with data on their selection and effective application in machines.

Fig. 1—Above—Variety of modern sealing materials. Extruded shapes, calendered and bulk types are among those widely used

on oils at all. They change little, if any, during or after application. Solvent is not used in this type, so they are 100 per cent solids. Therefore, drying is not necessary and, except for normal aging, they remain virtually the same as when first packaged, neither hardening nor shrinking.

Many of these high-solids, puttylike materials have a unique and very useful property which might be termed "delayed adhesion". Such materials are almost tack-free to touch and have only "token adhesion" when in momentary contact with surfaces. Yet, after a few minues contact, they appear to "grow" to the surface and adhere most tenaciously. This valuable property permits clean, easy handling and placement of the sealer without sacrificing high ultimate adhesion.

An important, relatively new form of pliable sealer is that marketed in extruded form, These are factory-extruded in round, flat or special shapes and packaged interleaved with special low-adhesion liners. They are available either cut to desired lengths or wound into rolls. (*Fig.* 1)

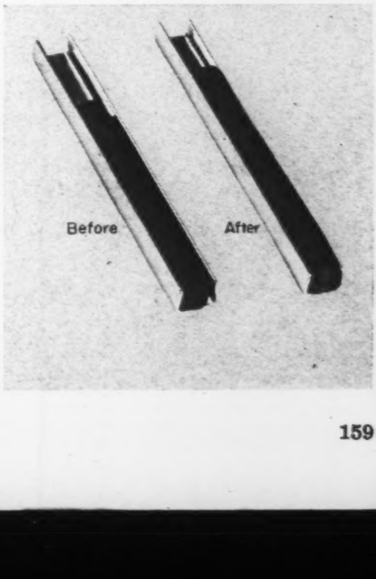
Sealers in this form are particularly well suited to large volume, assembly line operations. They can be designed to have either high or low adhesion, as the job may require. Some are reinforced by a fabric web to provide dimensional stability and eliminate stretch during application.

A recent innovation in extruded sealers is the type which expands and cures upon heating, resulting in a perfectly conforming sponge rubber gasket. They contain special "blowing agents" which cause them to increase as much as 150 per cent in volume when heated. One of these is illustrated in *Fig.* 2.

DRYING SEALERS: Sealers in this group set by evaporation of a solvent. As in paints and adhesives, solvents are used in many sealers to provide the desired consistency for application. Once applied, however, the solvent becomes an undesired constituent and must be eliminated to cause hardening of the sealer. Allowance must be made for solvent dissipation, both in design and in assembly of parts employing this type of sealer.

Consistency or hardness may change little or much when this type of sealer dries, depending on the amount of solvent it contains. Shrinkage upon drying is another important consideration, and again, the de-

Fig. 2—Right—Before and after views of expanding type sealer which forms a perfect fitting sponge rubber gasket on heat curing



gree of shrinkage is dependent upon the proportion of solvent present.

CURING SEALERS: This type of sealer has obvious advantages because it is transformed from a fluid or semifluid state into a solid mass by chemical reaction or physical change, rather than by evaporation of a solvent. Accessibility to air for drying is not a problem, either for design or production. Shrinkage is not a matter for concern, either, because there is usually little or no volume change upon curing.

The concept of sealing materials which neither shrink nor air dry may not seem too remarkable or important. However, these two properties have greatly increased the utility and simplified the commercial application of sealers, particularly in the metalworking industry. Whereas the usual practice has been to seal a joint from the outside (so the sealer could dry), curing sealers make it possible to seal from within. Instead of laying a bead of sealer along the outside of a lap seam, for instance, the use of curing type sealers makes possible the placement of the sealer between faying surfaces—where it is most effective. Component machine parts can be assembled at once without provision or waiting for drying. No longer must one design around the inconveniences of ordinary sealers.

Curing is usually accomplished by addition of a chemical catalyst or "accelerator" when ready for use. Heating may or may not be employed. If cured by an additive, accurate proportioning and thorough mixing of the two components is vitally important to assure a complete and homogeneous cure. Most difficulties with this type of product stem from haphazard mixing procedures.

Once the two components are mixed, curing begins and the sealer becomes progressively stiffer until it can no longer be applied. This intermediate stage of cure is called the "pot life" and its duration will be stated by the manufacturer. Thinning the mixed material with solvent to maintain a workable consistency while the cure is progressing will ultimately result only in an unsatisfactory cure. Pot life can often be extended by cooling or refrigerating the mixed material, taking out only a portion at a time for immediate use. Experience will dictate how large a batch should be mixed for consumption during the pot life period.

Temperature, and sometimes humidity, have a marked effect on pot life. Time to obtain complete cure will be specified by the manufacturer and this also may be greatly influenced by temperature. In fact, heating is sometimes recommended as a means of shortening cure time. In some instances, elevated temperature curing can cut cure times from a day or more to less than an hour.

Some sealers cure simply by heating alone, having an incorporated catalyst or other system which is activated by an increase in temperature. Others have unique curing mechanisms which are activated by ultraviolet light or other means. Time-temperature relationships are particularly important with heat-curing types. In all cases, manufacturers' instructions should be followed explicitly because some cures are critical.

Sealer Compositions: Sealer compounding is closely related to that in the rubber, paint and adhesive industries so far as raw materials and processing are concerned. Nearly all of the important polymers,

Table 1—Comparison of Physical and Chemical Properties of Sealer Binders*

Type of Binder	Physical Properties								Impermeability		Chemical Properties						Best Solvent Type[1]	Cost[2] (Per dry lb.)	Typical 3M Sealers
					Resistance To						Aging Resistance			Petroleum Resistance					
	Tensile Strength	Cold Flow	Resiliency	Flexure Life	Abras.	Tear	Heat	Cold	Water	Gas	Natural	Ozone	Light	Oil	Fuel	Ar. Fuel			
Natural Rubber	E	VG	E	E	E	VG	F	VG	E	G	F	P	F	P	P	P	Petroleum Naphtha	25c	None
GR-S Rubber	F-G	VG	F	G	E	F	F	VG	G	G	G	P	F	P	P	P	Petroleum Naphtha	23c	EC-873
Nitrile Rubber	G	VG	F	G	E	F	G	F-G	G	G	G	P	F	E	VG	G	Ketone or Ester	50-60c	EC-750 EC-1184
Neoprene Rubber	VG	F	VG	VG	E	G	G	F-G	F	VG	E	E	E	G	F	P	Aromatic Hydrocarbon	50-60c	None
Polybutene Rubber	P	P	P	E	P	P	G	F	E	E	E	G	G	P	P	P	Petroleum Naphtha	10-55c	EC-1167
Butyl Rubber	G	F	F	VG	G	G	G	G	VG	E	E	E	E	P	P	P	Petroleum Naphtha	21c	EC-1020 EC-1202
Vinyl Resin	F	F	P	F	G	F	G	P	F	F	G	F	P	E	E	P	Ketone or Ester	35-50c	EC-1164
Thiokol Rubber	P	P	P	P	P	P	P	F-G	VG	E	E	E	E	E	E	E	Ketone or Aromatic	80c-$1.00	EC-612 EC-801
Silicone Rubber[3]	P-F	P-E	P-VG	P-VG	P-E	P-G	E	E	G	G	E	E	E	G	P	P	None	$3.00-4.50	Exper.
Epoxy Resin	G	E	P	P	G	F	G	P	G	G	G	G	G	E	G	F	None	70c-$2	EC-1294
Reclaim Rubber	F	G	F	F	F	F	F	F	G	F	F	P	F	P	P	P	Petroleum Naphtha	10-25c	EC-373 EC-1209

* KEY: E = Excellent; VG = Very good; G = Good; F = Fair; P = Poor.

[1] "Best" considering solvency, toxicity, cost and other factors. Many of these binders may be water dispersed, also; some sealers contain no solvent.

[2] Approx. prices for June 1953. Where various grades are priced differently, a range is shown.

[3] Some silicone properties vary widely between grades.

resins, pigments, fillers, modifiers and solvents are used in one way or another. A few unusually costly ingredients are employed to produce certain desired characteristics for specialized uses, but most sealers are modestly priced when one considers that they are usually of much higher solids content than the average adhesive or coating.

BINDERS: Compounding has accomplished much in improving and modifying the physical properties of rubbers and resins, but comparatively little can be done to alter their chemical properties. Therefore, selection of the proper base material or binder is all-important in obtaining the desired chemical characteristics for any given service requirement. A review of the properties and structures of these materials may help us to understand their behavior and provide the basis for an intelligent choice for specific applications.

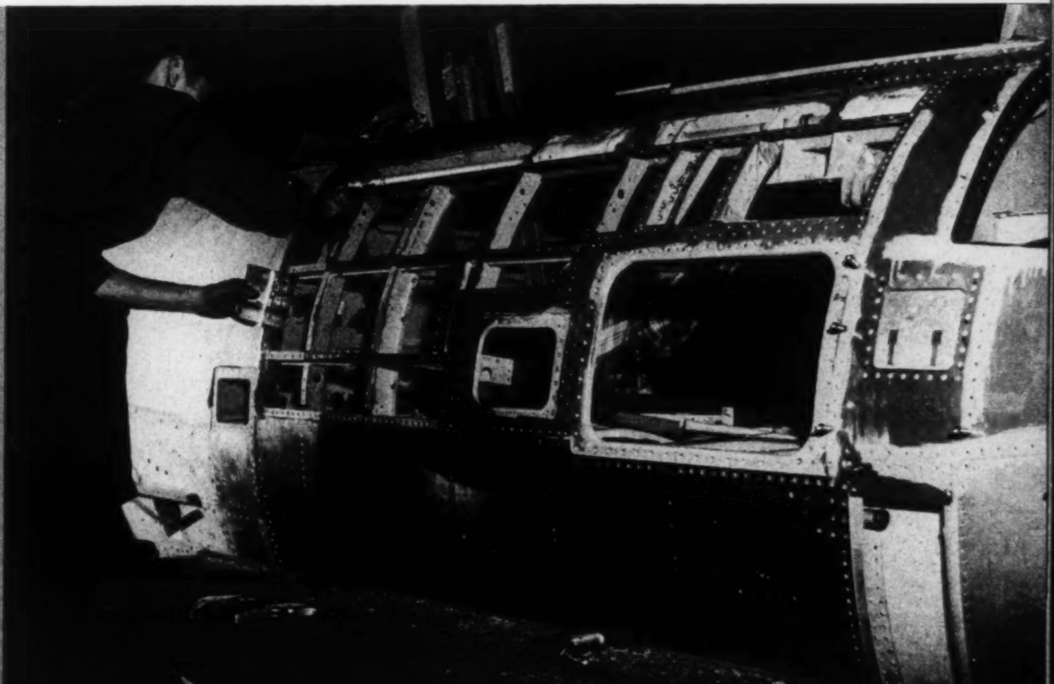
Rubber is elastic because it is comprised of a multitude of interlinking coils which are mechanically equivalent to millions of tiny springs. It is believed that the spiral structure of rubber results from its unique molecular arrangement. Early attempts to synthesize rubber were directed toward a molecular arrangement identical to that of natural rubber. Perhaps it is fortunate that this goal was never realized because several new rubberlike materials were developed which have unique and useful properties never known in the natural product. Vastly superior resistance to petroleum fuels and lubricants, heat, oxidation, sunlight and natural aging were among the dividends realized from this investment in scientific research. Greater uniformity of product and lower cost in several types of synthetics also resulted. For these reasons, the term "synthetic rubber" is an unfortunate misnomer which has caused the layman to look askance at some of the products made from them. "Elastomer," proposed by Harry L. Fisher, seems to be growing in favor as a more desirable and descriptive term for all rubber like materials, natural and synthetic.

Natural Rubber: Chemically, natural rubber is described as a 1, 4-addition polymer of cis-isoprene. These monomeric units join to form exceptionally long chains, believed to be from 4000 to 6000 units long. The mechanism of rubber vulcanization has not yet been explained to everyone's satisfaction, but it is generally believed to result from cross-linking between chains of rubber molecules by addition of sulphur at double bonds. The general characteristics of natural rubber are well known.

Butadiene Copolymers: Butadiene, a basic raw material for the production of several elastomers, is derived from alcohol, petroleum or natural gas. Though it can be polymerized alone, the rubberlike material, produced has little commercial value. Its chief importance lies in its copolymers with styrene and acrylonitrile.

Butadiene-styrene copolymers, commonly called GR-S, are by far the most important elastomers made today from the standpoint of total volume alone. They are made by copolymerizing aqueous emulsions of the mixed monomers, usually in butadiene/styrene ratios of about 3/1. These elastomers resemble natural rubber in many respects, including vulcanization with sulphur, and so have been widely used as a replacement for natural rubber. Similar compounding, elasticity, strength, and lack of oil resistance are

Fig. 3—Brush application of sealer on fuselage of Republic F-84 Thunderjet before attaching skin



found. Superior resistance to oxidation and many acids, alkalies and salts (except those which are strongly oxidizing) plus lower cost are desirable features. However, they are more difficult to mill and are less tacky.

Butadiene-acrylonitrile copolymers are commonly known as nitrile rubbers or Buna N. They are also made by copolymerizing aqueous emulsions of the mixed monomers in much the same manner as the styrene copolymers. Ratios of butadiene to acrylonitrile range from 4/1 to nearly 1/1. These nitrile copolymers resemble the styrene types somewhat in general appearance and processing qualities. They differ chiefly in their exceptional resistance to aliphatic and aromatic hydrocarbons, higher strength and better heat resistance.

Polychloroprene Rubbers: Known commercially as neoprene, these rubbers are essentially polymerized 2-chlorobutadiene. They are made by combining two molecules of acetylene to form monovinyl acetylene which is then combined with hydrochloric acid to give monochloroprene. This is emulsified and polymerized in a reactor to produce neoprene.

Unlike natural rubber and most other synthetics, neoprene is not vulcanized with sulphur. Zinc oxide is chiefly used as a catalyst or accelerator for vulcanization, which actually is a cross-linking between hydrocarbon chains and probably results in direct carbon-to-carbon bonds. It handles much like natural rubber on the mill.

Vulcanized neoprene outperforms natural rubber in resisting gasoline and oil and retains much more strength after swelling in aromatics. It also has better resistance to heat, sunlight, oxidation and gas diffusion.

Polybutenes: Polyisobutylene, better known as Vistanex, is made by polymerizing isobutylene at low temperatures in the presence of a catalyst such as boron trifluoride. Commercial materials contain small amounts of other isomeric olefins but in the resulting hydrocarbon chain the complete absence of double bonds makes vulcanization impossible. This also accounts for their high degree of chemical inertness. Depending on molecular weight (length of chain) these materials are obtainable in consistencies from soft, sticky gums to rather tough elastic solids.

Vistanex is soluble is petroleum naphthas, aromatics and chlorinated hydrocarbons, but resists alcohols, esters, ketones. These materials have excellent water resistance and outstanding impermeability to water vapor and gases in general. They are also odorless, tasteless and nontoxic. Considerable surface tack is retained, so that they collect dust and dirt unless overcoated. Their principal use in sealers is in making putties and calking compounds.

Butyl Rubber: The name "butyl" rubber covers a series of copolymers containing about 98 parts of isobutylene and 2 parts isoprene. Though the diolefin content is proportionately low, it imparts sufficient unsaturation to permit vulcanization with sulphur. This is in marked contrast to its close chemical relative polyisobutylene, which is almost completely saturated and incapable of vulcanization.

Uncured butyl rubber is tacky and tends to flow under its own weight. It is compounded and processed in much the same manner as natural rubber. When cured, this elastomer has the greatest impermeability to gases of all rubbers—natural or synthetic. This property, together with its excellent resistance to water, aging, tearing and abrasion, has made possible the production of better inner tubes than were previously made of natural rubber. In addition, it has remarkable resistance to chemicals like nitric, sulphuric, hydrochloric, hydrofluoric, and phosphoric acids, ferric chloride, caustics and other corrosive agents.

Like natural rubber, butyl is attacked by aliphatic hydrocarbons. Surprisingly, though, it has some resistance to aromatics (benzene and toluene) and to ethylene dichloride. It has far better resistance

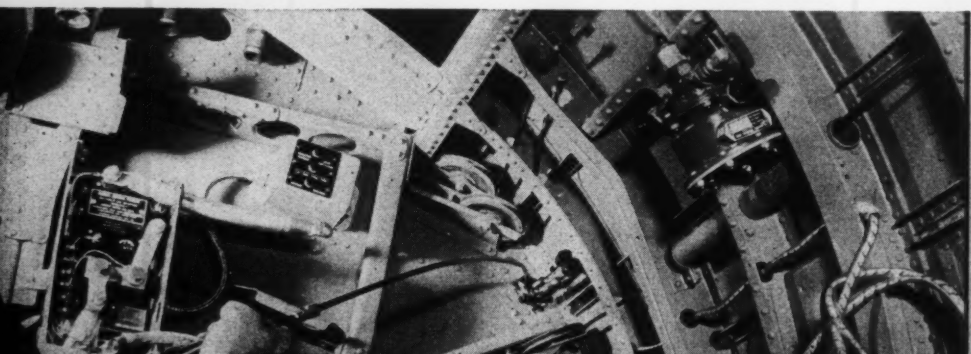


Fig. 4 — Pressure sealing around forward bulkhead apertures of a Grumman F9F Panther

to oxygen and ozone than natural rubber, as well as better flex resistance. When properly compounded, flexibility is retained at low temperatures.

Vinyl Polymers: Vinyl chloride and vinyl acetate can be polymerized individually or intermixed to yield the corresponding polymers and copolymers which are rubberlike in character. The chloride polymer is quite different from the acetate polymer. The former is a hard, tough material, quite insoluble in most organic solvents except nitrobenzene and cyclic ketones; the latter is a soft substance which melts at lower temperatures and dissolves in many solvents, including the alcohols, esters, ketones and chlorinated hydrocarbons. Incorporation of even a small amount of acetate polymer into the chloride polymer has a marked effect on its properties and acts, in function, as an internal plasticizer. Increasing the proportion of acetate radicals lowers the softening point and increases the ease of plasticization, solution, working and bonding. In practice, varying amounts up to about 15 per cent of acetate radicals are employed.

These resins are thermoplastic—cannot be vulcanized and have rather low softening temperatures. In general, they exhibit good chemical resistance and are not attacked by most oils and solvents. The copolymers are readily soluble in the aliphatic ketones. They are odorless, tasteless, nontoxic, water and weather resistant.

Vinyls are often used in sealers in the form of their plastisols. These interesting "inside-out" materials are essentially paste dispersions of finely powdered resin in suitable plasticizers. As such, no solvent is necessary and hardening is induced by heating sufficiently to cause the plasticizer to diffuse throughout the resin particles. Since no reaction occurs during hardening, there is little or no change in volume.

Polysulfide Rubbers: These versatile materials are better known by their trade name of Thiokol. Thiokols have little similarity to natural rubber. Several types find wide use in high-performance sealers. All have outstanding aging qualities, are remarkably resistant to water and weathering and, when cured, are virtually unaffected by many common solvents, notably the aliphatic and aromatic hydrocarbons. Most types retain some flexibility and resist shock at extremely low temperatures. Thiokol, unlike any of the other rubberlike materials, has the unique property of relaxing while under stress. Instead of eventually rupturing at the point of pressure, Thiokol slowly flows by a process of rheology. The least desirable property is odor which renders it unsuitable for uses where this is a factor.

Cured Thiokol polymers make excellent putties of the type described previously as having the property of "delayed adhesion". They have excellent handling qualities, yet have adhesion far in excess of their cohesive strength when applied to most surfaces.

Uncured Thiokol liquid polymers (notably those designated LP-2), are particularly useful for their ability to cure from a viscous liquid to a solid rubbery mass at room temperature without access to air. Unlike most other elastomers, Thiokols are not cured through a cross-linkage with sulfur. Their curing mechanism, in its simplest terms, is an oxidation reaction of the mercaptan group, resulting in molecular growth. Though all strong oxidizing agents will polymerize Thiokol, lead peroxide is generally preferred for its delayed action which permits a practical pot life after mixing. This type of sealer can be compounded to have either high or low adhesion to metal as desired. Low-adhesive types can be made to adhere to certain primers, making it possible to have the same sealer adhere in some areas but not in others.

Water lattices of Thiokol are also used to compound many useful sealers. Some are made by simply loading with fillers to make pastes or putties. Others are reversed phase dispersions in solvents.

Silicone Rubbers: These elastomers are used to a lesser extent in sealers—they have several outstanding

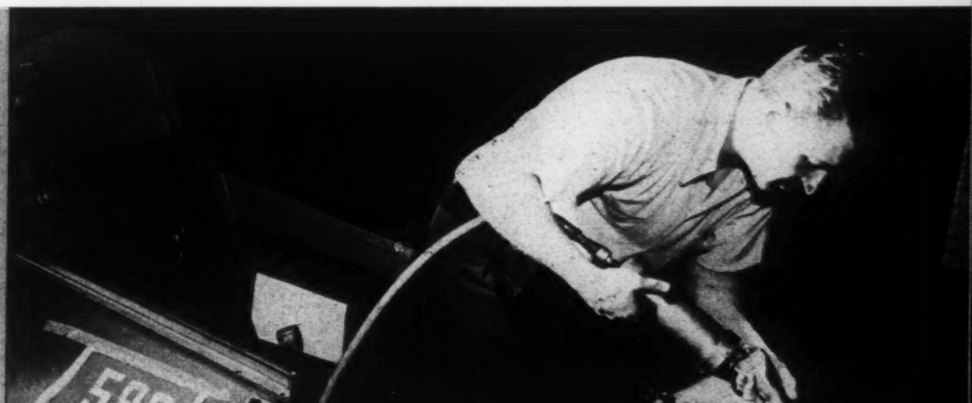


Fig. 5—Pressure gun sealing of cockpit canopy opening on a Grumman F9F Panther

properties and some serious limitations. Curing is accomplished by reacting with such compounds as benzoyl peroxide at elevated temperatures. And this brings up one of their major drawbacks for use as sealers—to date, there is no satisfactory way of curing the silicones at room temperature.

Silicone rubbers are remarkably little affected by wide extremes of temperature—one type will change only 20 Durometer points from −120 to 500 F! Most silicones have surprisingly poor resistance to chemicals and to oil and aliphatics in general. Their cost (in the $4 per pound range) is also a deterrent to their wider use.

Epoxy Resins: Probably the newest class of resins to gain prominence in sealer manufacture is the epoxy family. These resins are characterized by a chain molecule which has an epoxy group at each end. Typical are condensation products of epichlorohydrin and bisphenol, reacted at about 100 C in the presence of sodium hydroxide. Curing is effected by adding a catalyst which usually consists of a diamine, a dibasic acid or both. The cure will proceed at room temperature, but is greatly accelerated by heating.

The epoxy resins are best known for their high strength and excellent adhesion to many surfaces. They are also highly resistant to water, concentrated acids and alkalies and most solvents. Their heat resistance is not exceptional, though, and they have rather sharp melting points. Brittleness is another weak point of the epoxies, though proper compounding can improve this greatly in some instances.

Reclaim Rubbers: Many excellent low-cost sealers are made from reclaimed rubbers. Carefully selected, graded and processed, these materials are not to be considered as shoddy or low-quality in any way—neither are they all cheap. Some grades cost more than some new synthetics. Tire tubes are the choicest grades, but carcass stock is also used extensively. Both natural and synthetic reclaims are available. Butyl is the chief synthetic reclaim.

In the preceding paragraphs, most of the important binders used in modern sealers have been outlined. How some of them perform in relation to each other is indicated in TABLE 1. No attempt has been made to give specific values because they vary considerably with different grades and compounding. Sealers compounded from these materials have properties which parallel those of their binders, though compounding can do much to improve some characteristics. Note particularly that natural rubber excels in most physical properties, while the synthetics are generally better in chemical properties.

REINFORCING PIGMENTS AND FILLERS: Contrary to popular belief, fillers are seldom used only to reduce cost. They contribute many valuable properties. In some instances they greatly improve physical properties—illustrated by the use of carbon black in automobile tires to improve strength and abrasion resistance. In other cases, fillers are used to reduce the tackiness of the binder. Fibrous fillers such as asbestos are of value in building materials of heavy consistency. In others, the drying rate may be slowed by use of proper fillers.

MODIFIERS: For simplification, all the various materials that are used to change the properties of the binders are grouped under the heading of "modifiers":

1. *Accelerators* and other cross-linking or polymerizing agents are used with natural rubber and most synthetics. In this category is the sulphur used to vulcanize natural rubber, reclaim rubber, and some synthetic rubbers. Lead peroxide used for curing Thiokols is another example.
2. *Plasticizers* are chiefly used to eliminate brittleness, improve resiliency, and, in some cases, to enhance adhesion of a compound by promoting better wetting of surfaces. Usually these ingredients improve low-temperature flexibility, but at the same time adversely affect the high-temperature or solvent resist-

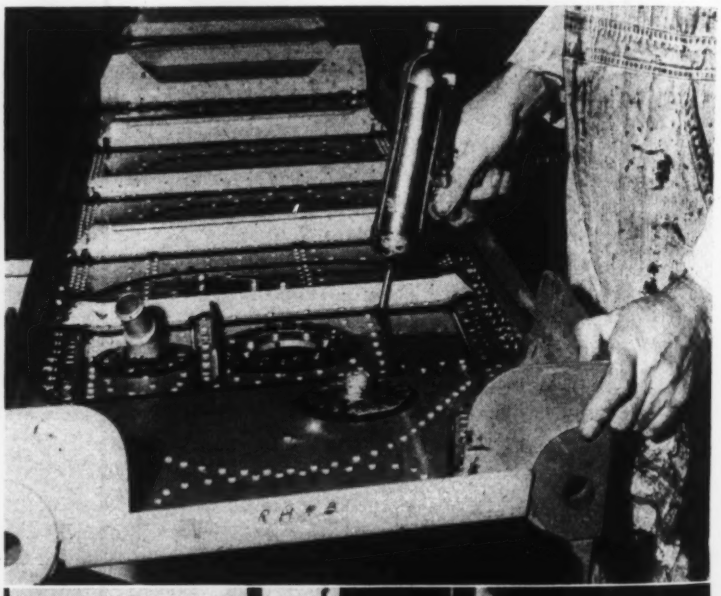


Fig. 6—Applying sealer to span web and around rivets for integral fuel tank on a Douglas DC-6

ance of the binder.

3. *Tackifying agents* include those natural or synthetic resins which are employed to improve adhesion of the binder to various surfaces.

4. *Stabilizing agents* are those chemicals which are added to improve resistance to heat, light, or chemical breakdown.

SOLVENTS AND VEHICLES: Solvents are employed as vehicles to put solid constituents into a usable form for easy application. Once applied, they must be eliminated to harden the sealer, so that it can perform the intended job. The ideal solvent is one capable of dissolving or dispersing the dry ingredients, gives a reasonable working time, evaporates fast enough to be practical for production operations and is not dangerously toxic or inflammable. Since these properties are mutually exclusive, it is sometimes necessary to compromise between the high-boiling solvent with a long working range and a low-boiling solvent which causes the sealer to dry rapidly. Sometimes it is possible to blend several solvents to give the desired properties.

For natural rubber, reclaim rubber and GR-S, petroleum naphtha solvents are widely used. Neoprene compounds require aromatic hydrocarbons; for the Thiokol and nitrile rubbers, it is necessary to use ketones, esters, or chlorinated solvents. It is unfortunate that the most expensive binders generally require the most expensive solvents, thus preventing a welcome compensation of cost factors.

In some instances, it is possible to disperse the basic ingredient in water, as with GR-S and Thiokol lattices. This has some advantages from cost and flammability or toxicity standpoints. The principal disadvantage of water dispersion is their inability to withstand freezing without serious damage, though some progress is being made to eliminate that deficiency.

Uses for Sealers: Among the hundreds of specialized materials used in airplane manufacture are many types of sealers, *Fig.* 3. As air speeds go up, it becomes more vital that exterior surfaces approach aerodynamic perfection. Sealers help to achieve this by filling joints and smoothing surface irregularities. High altitudes make cabin pressurization necessary for personnel comfort and survival, *Fig.* 4. Sealers are used to make the fuselage watertight and pressure-tight, *Fig.* 5. Some of these sealers are based on nitrile rubber, while others are Thiokol types.

Speeds are now in the range where air friction raises the skin temperature considerably and planes now on the boards will have to function at temperatures over 250 F. These same aircraft do not travel at fantastic speeds all the time, however, and may within a matter of minutes slow to a point where the normal −70 F cold at high altitudes takes over. This means that sealers are needed to perform under new conditions. Sealers must remain effective over the entire operational range. Metals expand and contract markedly. Sealers must maintain adhesion, not soften or become brittle, withstand the rigors of outdoor exposure, vibration, and other abuse. Besides this, they must be capable of application by personnel without extensive technical training.

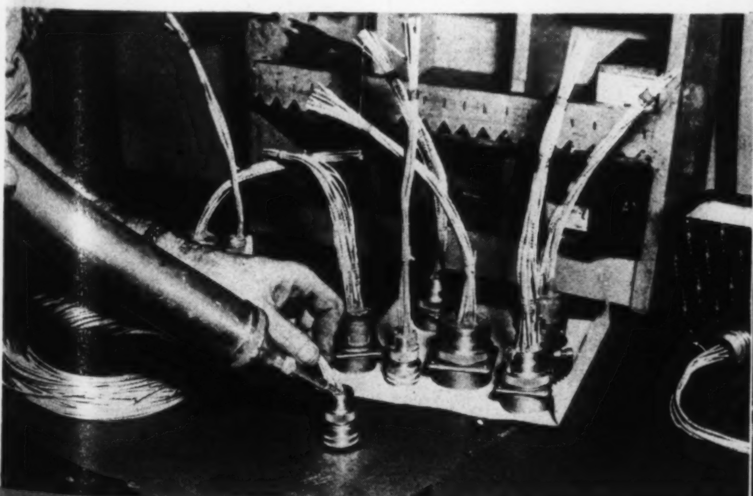


Fig. 7—EC-1120 potting compound, which is unaffected by vibration, used to seal electrical wiring in plugs used on McDonnell fighter aircraft

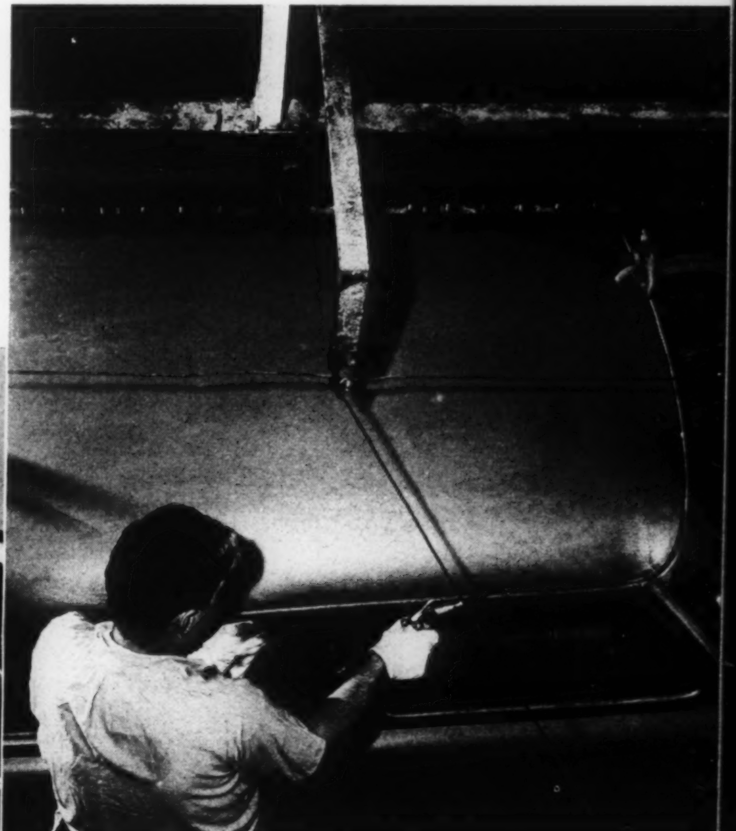


Fig. 8—Flowing sealer into Ford rain gutter. Material cures during paint drying cycle

Add to all of the foregoing service requirements the property of withstanding constant immersion in high octane fuels containing aromatics, and we have many of the properties required for sealing integral fuel tanks. In the strict sense, these are not tanks at all, but merely compartments within the wing which are sealed liquidtight for storing fuel. Catalytic curing Thiokol compounds have handled this difficult assignment well for several years. One class of compounds is used for production sealing at the factory where all the desired facilities are available for mixing and applying these sealers. *Fig.* 6 illustrates some of the steps in production sealing integral fuel tanks.

Field repair of fuel tanks is a different proposition where speed and simplicity are paramount to minimize ground time. A number of different types of repair kits are on the market to meet this special need. Since thorough mixing of the catalyst with the base sealing compound is vital to assure satisfactory performance, much work has been done to remove the guesswork from this important operation. Most common is a two-component package whose preweighed contents are mixed in the larger of the two containers just before use.

Some of the smallest uses in aircraft take the most engineering. For instance, the RATO (rocket assisted take-off) system uses white fuming nitric acid as a propellent, and this highly active material must be contained and prevented from damaging other parts of the aircraft structure. Sealers to resist this corrosive chemical had to be developed to isolate the compartments where the rocket motors are located and the fuel is stored. Flexible potting compounds are used in some types of electrical connector plugs to provide insulation and protect against corrosion, *Fig.* 7. These materials are just now coming into more common use and will find application in industries other than aircraft. Windshields and windows must be effectively sealed to be weathertight and to maintain internal cabin pressure.

The automotive industry offers many challenges in sealer application. Liberal use of puttylike compounds is made all over auto bodies for weather sealing. Inside the trunk such materials are "thumbed" into places where leaks might develop, such as around the tail light openings, gas tank filler neck, the latch fittings and the holes where chrome trim attachment clips enter the body. Similar uses are found in the engine compartment, particularly around the firewall. More is used inside the doors and other places where it doesn't show.

Perhaps more important is the sealing of drip rails

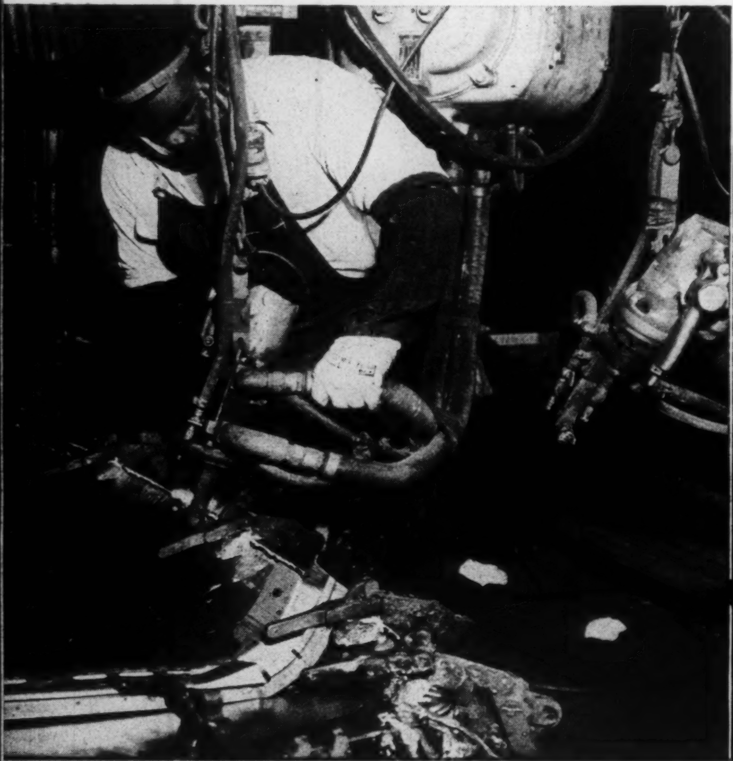


Fig. 9—Spot welding of auto body using "weld-thru" sealer material

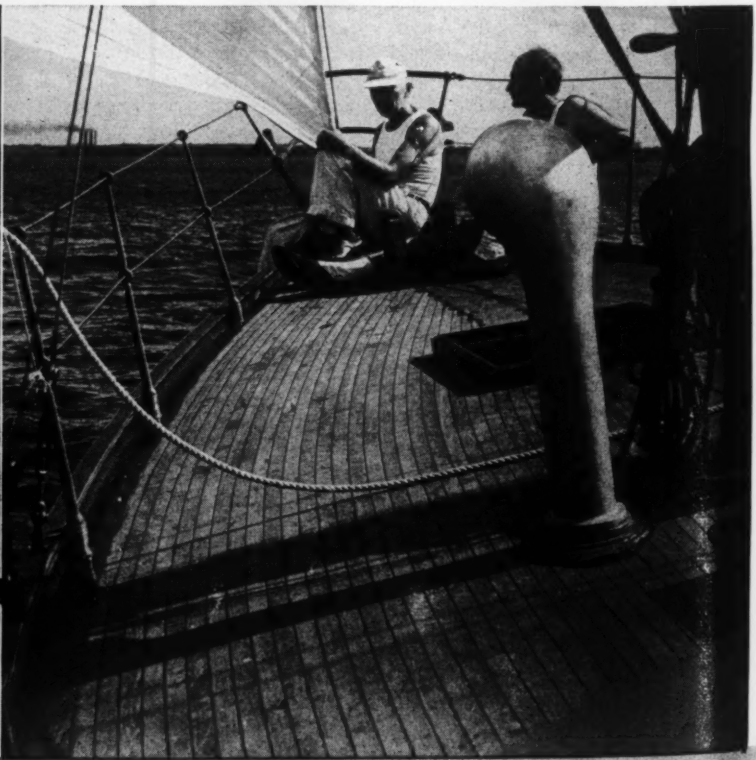


Fig. 10—Section of boat deck calked with curing type sealer is unaffected by weather conditions

or rain gutters, *Fig.* 8. Here the best practice is to run a bead of sealer along the spotwelded seam after priming but before the final paint is sprayed. A vinyl plastisol sealer is employed which cures in the oven along with the paint. Body repairs also require sealers. Some of these operations resemble aerodynamic smoothing in aircraft, where sealers are used instead of metallic solder to fill dents and small holes. After setting, these "synthetic solders" may be sanded and finished just like the surrounding metal.

Sealing between bolted members, such as around wheel housings, calls for a special sealer. A peculiar shaped extrusion is tailor-made to fit along such seams and is furnished in proper lengths to fit the job. In addition, this material is designed to expand as the body passes through the paint ovens, curing to a tough sponge rubber. This is an instance of a product engineered exactly to do a specific job. A similar engineering job is done to furnish a product especially for sealing door hinges.

Welded seams once had to be sealed from the outside—until sealers were developed which could be spread between faying surfaces before assembly. These materials withstand the heat and pressure of spotwelding without splattering, burning or interfering with the quality of the weld. These are called "weld-thru" sealers and are illustrated in *Fig.* 9.

The Navy has many sealer needs. Here there is a minor revolution brewing in sealing wooden hull and deck seams on aircraft carrier flight decks, air-sea rescue boats and other utility craft. Development is proceeding on Thiokol sealers which cure in the seam, *Fig.* 10 and are virtually unaffected by natural weather conditions. Such sealers also stretch and compress to maintain a tenaciously adhering seal, despite movement of planking caused by swelling and shrinking or rough seas. When used between layers of double hull planking they contribute materially to the strength of the hull structure in addition to bonding the layers together and providing a moisture barrier.

Home appliances have many components which require sealing. One washing machine agitator has two plastic shells which are joined and sealed together as shown in *Fig.* 11. Refrigerator and freezer cold compartments must be sealed off from the rest of the machine by compounds which will withstand vibration at low temperatures and the ever-present moisture. Important here, too, is a compound which will not impart taste or odor to the food. Heat conductive sealers have done much to improve the thermodynamic efficiency of the cooling units by increasing the contact area of the coolant coils to the shells as explained in *Fig.* 12.

Army Ordnance uses sealers in many interesting ways. Prisms and lenses are sealer-mounted in several types of tank vision blocks and periscopes, fire control instruments and other optical devices. In one case, a glass eyepiece is bonded and sealed directly to Plexiglas. This sealer must not alter the optical properties of the instrument, yet has to function under

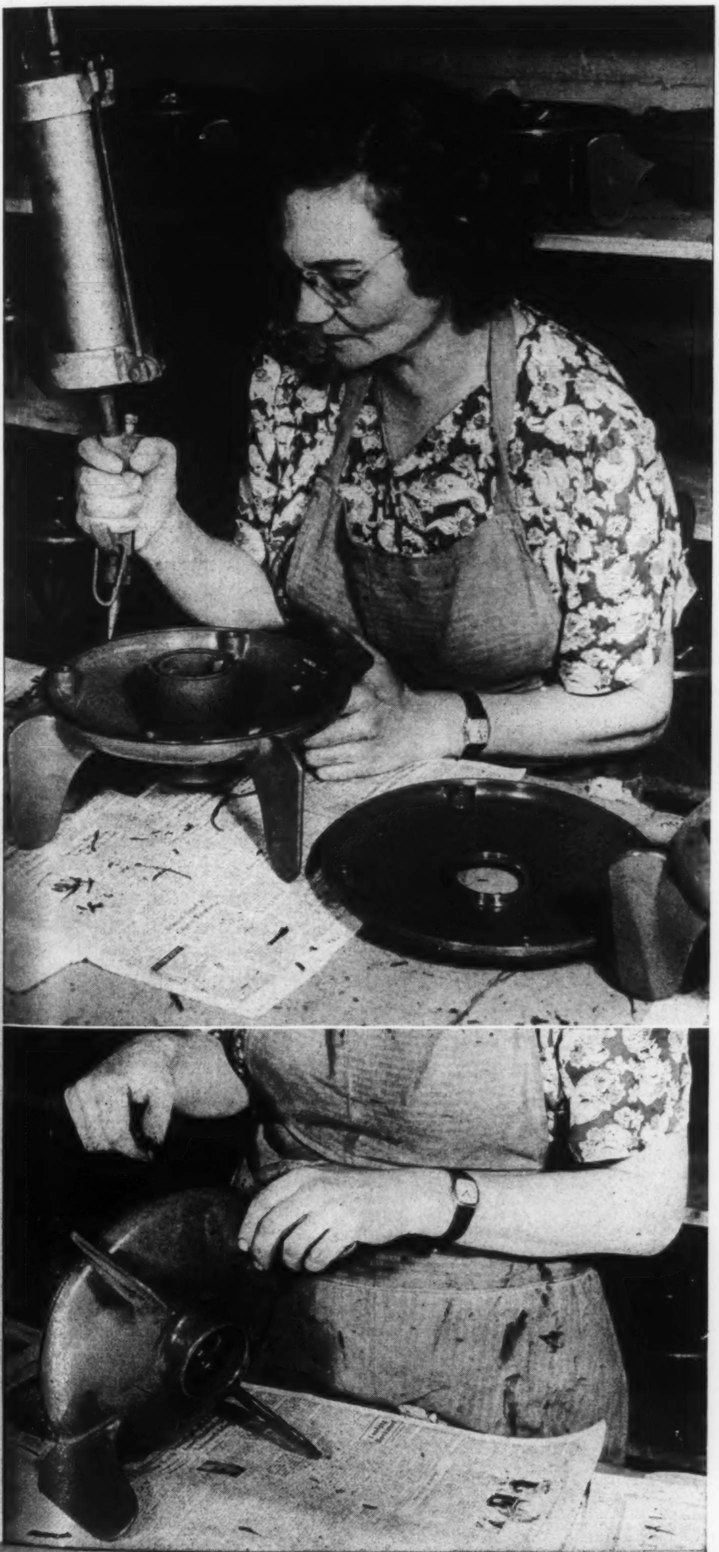


Fig. 11—Sealer being applied and excess being trimmed after assembly of two plastic shells of Voss washing machine agitator

arctic or tropical conditions. Here a water-clear sealing material which cures by heat and exposure to ultraviolet light is employed. Sealers also find use in many types of missiles and projectiles to isolate the different components (fuses, propellents, charges, etc.) from each other and from outside conditions.

Applying Sealers: Sealer application methods are influenced by both the consistency of the product and the nature of the job to be done. Ordinarily the simplest of standard equipment is quite adequate. However, production can often be accelerated by use of special devices or techniques.

The first requirement is a clean surface. Like adhesives and coatings, sealers cannot bond properly to a surface which is wet, oily or dirty. Solvent washing or vapor degreasing will usually suffice— or, almost any standard paint preparation procedure may be used. Adhesion is usually best to a bare metal surface or one which has had some prepaint treatment such as anodization, phosphatization or other chemical or electrochemical treatment. Some paints prevent good sealer adhesion, while others are lifted or attacked by the sealer solvents. Sometimes, of course, a good, sound paint base is not objectionable if compatible with the sealer—only a test will tell for sure.

Most sealers adhere directly to ordinary surfaces, but a few sealers and some kinds of surfaces need special pretreatment or primers. One group of Thiokol-base sealers will adhere only to a primed metal surface, for instance, while other Thiokol types have outstanding adhesion to bare metal.

Thin nonviscous sealers can sometimes be applied by brush, by fill-and-drain techniques or by trigger operated pressure oil cans. Pressure flow guns and hand caulking guns are probably the most widely used pieces of equipment for sealer application. Several standard types are available from numerous manufacturers in a wide variety of sizes and shapes of application tips. All sorts of modifications and special attachments are used to meet the specialized needs of large-volume production applications. Metering devices are used to deposit only a predetermined amount of sealer on a given area. Automatic controls to start and stop the flow of sealer are sometimes devised.

Special guns which mix two component sealers automatically are made by at least one manufacturer. Guns with replaceable cartridges which can be refrigerated to extend the pot life of catalytic curing sealers until ready for use have been developed. One of these is shown in *Fig.* 6.

Heavy, putty-like sealers are usually applied by hand. A gob is rolled between the hands to form a ribbon of appropriate size which is then "thumbed" into place. Putty knives are also used to apply or smooth such sealers. In production, high-pressure extruders are used. Those of the meat grinder type extrude beads or ribbons of desired size and shape which are then positioned by hand on the unit to be sealed. Pile driver types are used to feed guns which will "pay" beads or ribbons directly in place.

Extruded sealers are the simplest to apply. They are simply stripped off the liners and placed in position by hand, trimming to desired length if not precut. Those used in faying surfaces of seams are positioned before parts are assembled and bolted or riveted. Types which are designed to expand when heated are often placed before the unit is painted; curing takes place later as it passes through the paint baking ovens.

Design for Sealers: Few special considerations must be observed in designing for the use of sealers. Ordinarily, design is simplified. In some instances it must be borne in mind that parts or units should be designed for an assembly sequence which will permit accessibility for their application at the proper time.

Where air-drying types are employed, provision must be made for accessibility to air for solvent dissipation. Sealers of a type which cold flows under pressure should be located on the on-pressure side of a joint to assure permanence of the seal. If heat is required for curing, other parts of the assembly should be capable of withstanding this environment

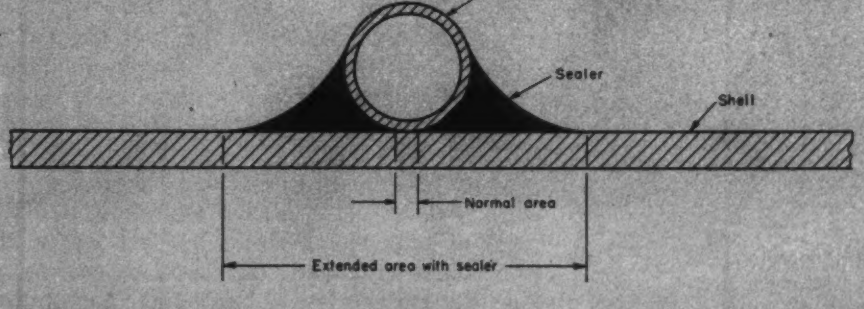


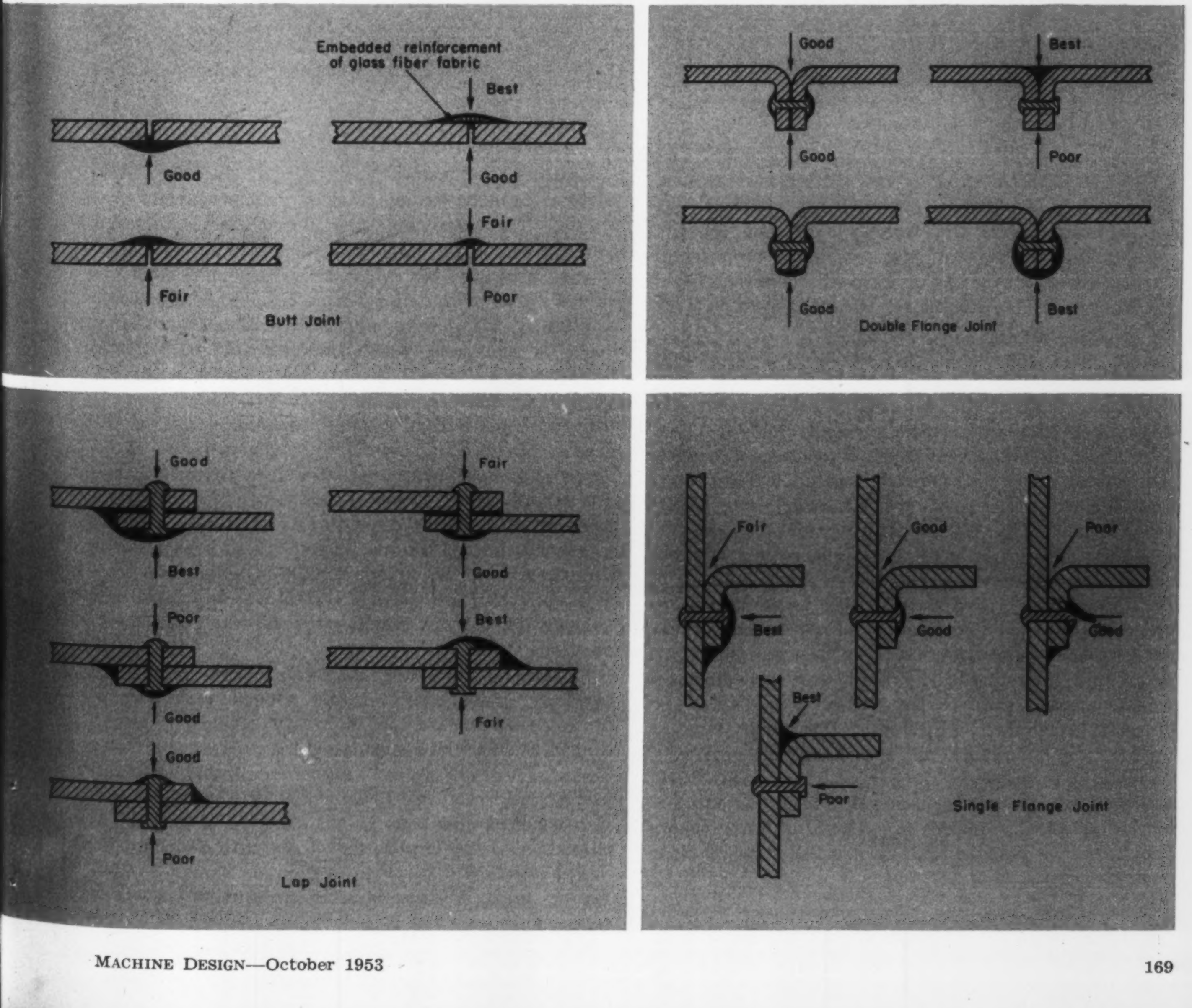
Fig. 12—Sketch of cooling tube with sealer showing normal heat transfer area of tube to sheet and extruded transfer area created by conductive compound

without damage.

Sketches in *Fig.* 13 illustrate good and bad design practice in butt, lap, single-flanged and double-flanged joints. Rivets are shown in each case, but it makes little difference whether rivets, bolts or spot-welds are used—the principles are the same. The direction of pressure (fluid or gas) is indicated by an arrow in each case—assuming that there is pressure on the joints, of course. Where a sealer is used on the off-pressure side, a curing type is generally best because of better adhesion and less cold flow; an air-drying type is second choice. When sealing in the faying surfaces, a curing type is best, but a pliable type (preferably extruded or calendered) is usually satisfactory if the pressure is not great enough to cause cold flow. When sealing of the on-pressure side, any type is usually satisfactory.

Selection of proper sealer for each end use is most often the function of the designer. Careful analysis of all production and service conditions under which the sealer must perform is vital to the intelligent selection. Matching these requirements against the characteristics of available sealers is the next step. Because the field is changing so rapidly that sealer manufacturers are unable to keep catalog and other literature completely current, it is most desirable that the supplier be consulted as early in the design stages as possible.

Fig. 13—Good and poor design of joints for sealer application. Any fastening means can be used — rivets, screws, bolts or welds. Where pressure is to be encountered the arrow indicates joint orientation. Faying surface sealing is not practical where joints are highly stressed or subject to vibration


Embedded reinforcement of glass fiber fabric
Best
Good
Good
Fair
Fair
Poor
Butt Joint
Good
Best
Good
Poor
Good
Best
Double Flange Joint
Good
Best
Fair
Good
Poor
Best
Good
Fair
Good
Poor
Lap Joint
Fair
Best
Good
Good
Poor
Good
Best
Poor
Single Flange Joint

DATA CHARTS FOR plastics

A comprehensive summary of the important physical, thermal, electrical and chemical properties of engineering plastics

ENGINEERING plastics are available today in a variety of chemical formulations, modifications for particular uses, and forms. New compositions with striking characteristics are constantly appearing, further complicating the job of materials selection. Yet the practical usefulness of the older plastics must not be overlooked.

To provide a basis for broad preliminary evaluation of plastics currently being used in design, the data charts and table on the following pages are arranged in families of plastics with generally similar characteristics. Plastics available for molding, extrusion and casting, and as laminated and plain sheet have been included; many of the latter are also available as rod, tubes and other cross-sections. Filaments, sheeting, film, wire coatings, finishes and similar "nonstructural" forms of plastic are not included.

Although the charts have definite value as preliminary guides, final selection should not be made without further investigation. Many of the properties are only approximate indicators of true service conditions. As an example, the Izod impact test involves the use of sharply notched specimens. For many plastics (nylon, for example), impact strength is greatly affected by geometry of the part. If large-radii fillets are used, as is common in actual practice, impact behavior is greatly improved. Therefore, the charts should not be used to provide detailed data or close comparisons.

Utilizing the Charts: Chart data are largely adapted from information supplied by primary plastic producers.* In most cases, the information is included for representative compositions covering a wide range of each property, but minor modifications beyond the values noted in the charts may be possible by choice of slightly different formulations, fillers, plasticizers, etc. By the same token, however, no one plastic is likely to supply all favorable attributes in the extremes noted for each family.

Certain generalizations are inherent in use of the charts. Degree of flammability, for instance, is indicated for specimens over 0.050-inch thick and may not hold true for thinner specimens. To provide a basis for comparison, dielectric strength values shown are for ⅛-inch thick specimens; for thinner sections the value may be much higher. Similar considerations are true for water absorption, in which the actual percentage may change with differences in thickness.

Resistance to specific chemicals should be checked carefully, since chemical and solvent resistance is pretty much a case for individual consideration and cannot be completely specified in abbreviated form. Under "flexural stress" and "compressive stress," several "no fracture" notations occur. In these cases the specimen slips through the supports or is buckled; thus, there is no implication of strength or lack of it.

For all plastics included in the data charts, the following table outlines specific compositions, characteristics and typical uses.

**Technical Data on Plastics,* Manufacturing Chemists Association Inc., Washington, D. C., 1952.

PLASTIC COMPOSITIONS AND CHARACTERISTICS

1.—Urea Formaldehyde

Composition: Combined with pure alpha cellulose fillers.

Outstanding Characteristics: Colorless, translucent and light-fast; almost any color can be obtained with pigments and dyes; resistant to all known organic solvents; hard, permanent surface; electrical properties not greatly affected by high humidity or water exposure.

Typical Uses: Closures; housings and boxes; electrical parts.

2.—Melamine Formaldehyde

Composition: Unfilled or alpha-cellulose filled (translucent); mineral filled (brown only); cellulose filled (brown or black); chopped-fabric filled (mottled tan, mottled white and several colors).

Outstanding Characteristics: Rigid; hard surface; unaffected by common solvents; highly flame resistant depending on filler; unfilled or alpha-cellulose filled for translucent or light-fast, nonfading colored moldings with good dimensional stability; mineral filled for electrical uses, particularly at elevated temperatures—arc resistance remains high in presence of moisture; chopped-fabric filled for higher shock resistance and flexural strength; cellulose filled for electrical uses where metal inserts present a special problem.

Typical Uses: Food handling machinery; switchgear; electrical parts.

3, 4, 5, 6, 7.—Phenolics

Composition: Phenol-formaldehyde and furfural-aldehyde-phenol combined with cellulose (general-purpose), flock, paper, pulp or fabric (shock-resistant), cord (high shock resistance), mineral flour, yarn or fiber (electrical, and shock and heat-resistant); combined with rubber and filled with wood flour, cotton flock, chopped fabric or asbestos.

Outstanding Characteristics: Hard and rigid; little softening, if any, under heat—depending on composition; very slight change on indoor aging except slight dimensional changes with unusually wet or dry atmospheres; good electrical insulating properties; dark colors are highly preferred, since light colors darken on exposure to sunlight.

Typical Uses: Camera cases; machine and instrument housings; radio cabinets; telephones; connector plugs, circuit-breaker bases, instrument panels, terminal blocks and other electrical parts; motor housings; wheels, pulleys and knobs.

8.—Alkyd

Composition: Unsaturated polymerizable alkyd combined with granular-mineral, putty-mineral or glass-fiber (matlike) fillers.

Outstanding Characteristics: Outstanding dimensional stability, permitting use of inserts without warping or cracking; highest arc resistance of thermosetting molded plastics; good dielectric strength, resistivity and insulation resistance; strength properties approach best low-pressure laminates.

Typical Uses: Magneto rotors, terminal blocks and other electrical parts; switch and circuit-breaker covers and bases.

9.—Silicone

Composition: Liquid silicone resins with chopped glass-fiber filler; occasionally a finely ground inert filler, such as titanium dioxide or diatomaceous earth, is added for improved appearance and sharper detail at the expense of mechanical properties.

Outstanding Characteristics: Extremely heat resistant; excellent arc resistance; good dielectric properties over wide frequency range; somewhat lower mechanical strength than phenolics; requires long molding cycle.

Typical Uses: Circuit breakers; naval switchgear; switch parts.

10.—Epoxy

Composition: Condensation polymers varying from liquids at room temperatures to high-melting point solids; resins are converted from thermoplastic state to hard, infusible, insoluble polymers which have practically no thermoplastic properties by curing either at room or elevated temperatures depending on composition; nonreactive or reactive plasticizers are used to improve impact strength, increase flexibility, and reduce viscosity of cured resin; sand, slate, porcelain powder, powdered silica, glass, asbestos or micronized alumina may be used to reduce shrinkage.

Outstanding Characteristics: Excellent electrical, thermal and strength properties; retains dielectric properties under severe temperature and humidity conditions; good adhesion to most materials including metals; low water absorption.

Typical Uses: Casting and potting resins are presently used—some applications as laminating resins are being investigated.

11.—Cast Phenolics

Composition: Phenol formaldehyde, catalysts and additives converted to casting by baking in lead molds for several days at temperatures under 100 C.

Outstanding Characteristics: Good machinability combined with low tooling cost; transparent, translucent or opaque in wide range of colors and mottled effects, including white and ivory; good arc resistance and dielectric strength.

Typical Uses: Decorative boxes, handles, etc.; colored housings, etc.; jigs and fixtures.

12, 13, 14.—NEMA Standard Laminates

Composition: Phenolic, melamine or silicone resins plus sheet materials, impregnated and laminated under high temperatures and pressure; only those laminates covered by NEMA Publication LP 1-1951 are included.

Outstanding Characteristics: High strength, resilience, and wearing properties; excellent electrical properties and heat resistance; paper-base for punching, engraving and some electrical uses; fabric-base for strength, toughness and impact strength; asbestos-base for higher heat resistance; glass-base for heat resistance, excellent electrical properties and dimensional stability.

Typical Uses: Paper-base—panels, switch plates, switch rotors, nameplates, dials, etc.; fabric-base—gears, pinions, cams, bearings, valve disks, friction disks, terminal strips; glass-base—motor and electrical insulation, power equipment in marine applications, circuit-breaker parts.

15.—Melamine Laminates

Composition: Resin laminated with paper, glass fabric or cotton fabric.

Outstanding Characteristics: Very high strength; hard, abrasion-resistant and light-fast; good electrical properties; high arc resistance with no tendency to track after exposure to arcing.

Typical Uses: Panel instrument boards; panels; counter tops and tables.

16, 17.—Polyesters and Allyls

Composition: Allyl esters or materials formulated from reactive alkyd resins using styrene or allyl resin monomer; cast allyls are unfilled; cast polyesters are filled with silica, calcium carbonate, jute, whiting, glass fiber, cotton linters, etc.; reinforced types (low-pressure or contact resins) are filled with chopped glass strand, woven glass fabric or paper.

Outstanding Characteristics: Basically clear, ranging in color from water-white to yellow; can be dyed, or pigmented and filled, to produce whites and wide color range; translucent, opaque and mottled polyester castings can be made; high strength; high resistance to crazing in cast or sheet form; excellent resistance to heat distortion; good chemical resistance; polyester properties can range from hard and rigid to flexible and tough depending on initial resin.

Typical Uses: Cast—aircraft enclosures, dials, indicator and gage covers, lenses, chemically resistant fittings; reinforced—boats, aircraft parts, housings and panels, automotive parts, racks.

18.—Acrylics

Composition: Polymerized form of acrylic acid derivatives.

Outstanding Characteristics: Excellent clarity and transparency; best resistance of transparent plastics to sunlight and outdoor weathering; smoother surface than drawn silica glass, although hardness is much lower; transparent, translucent or opaque colors can be produced; tendency to craze under stress or moderately high temperatures.

Typical Uses: Transparent aircraft enclosures; music and vending-machine parts; automotive parts; reflectors; appliance parts; nameplates.

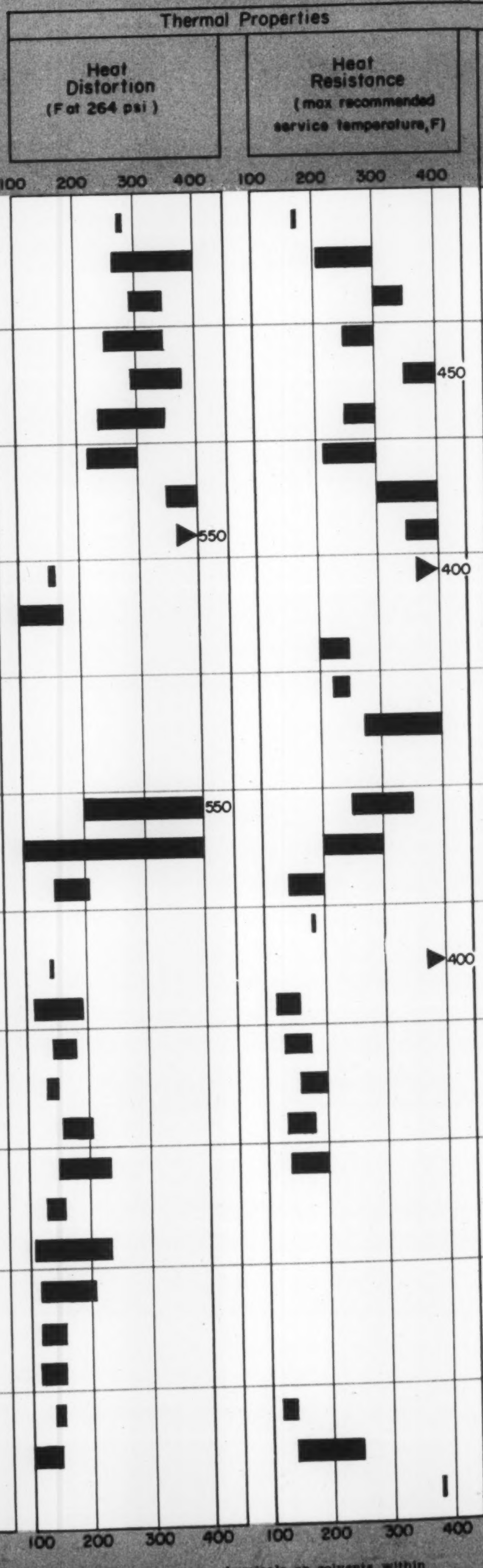
19.—Polyethylene

Composition: Polymerized form of ethylene.

Outstanding Characteristics: Remains flexible and tough over wide

(*Table continued on Page* 176)

Number	Plastic	Thermoplastic	Thermosetting	Form or Mfg. Method								Thermal Properties	
				Molding									
				Injection	Compression	Transfer	Extrusion	Low-pressure lamin.	High-pressure lamin.	Sheet	Cast	Inflammable	Self-extinguishing
1	Urea-formaldehyde		●		●	●							●
2	Melamine-formaldehyde		●	●	●	●							●
3	Gen. purpose phenolics		●		●	●							●
4	Shock-res. phenolics		●		●	●							●
5	Shock & heat resistant phenolics		●		●	●							●
6	Electrical phenolics		●		●	●							●
7	Rubber phenolics		●		●	●							●
8	Alkyd		●		●	●							●
9	Silicone		●		●	●							●
10	Epoxy resin										●		
11	Cast phenolics		●							●	●		●
12	Paper-base laminates (2)		●						●	●			
13	Fabric-base laminates (2)		●						●	●			
14	Glass & asbestos laminates (2)		●						●	●			
15	Melamine laminates		●						●	●			
16	Polyesters & allyls		●					●		●		⊘	⊘
17	Polyesters & allyls (cast)		●							●	●	⊘	⊘
18	Acrylic	●		●			●			●		●	
19	Polyethylene	●		●	●		●			●		●	
20	Polytetrafluoroethylene	●		Special (4)						●			●
21	Polyvinyl formal & butyrate	●	(5)	●	●					●		●	
22	Vinyl chloride & copolymers	●		●	●		●			●		⊘	⊘
23	Vinylidene chloride	●		●	●		●						●
24	Polystyrene	●		●	●		●			●			
25	Modified styrenes	●		●	●		●			●		●	
26	Cellulose acetate (sheet)	●								●		⊘	
27	Cellulose acetate	●		●	●		●					●	
28	Cellulose acetate butyrate	●		●	●		●					⊘	⊘
29	Cellulose propionate	●		●								●	
30	Ethyl cellulose	●		●	●		●			●		●	
31	Cellulose nitrate	●								●		●	
32	Nylon	●		●			●						●
33	Trifluorochloroethylene	●		●	●	●	●			●			●



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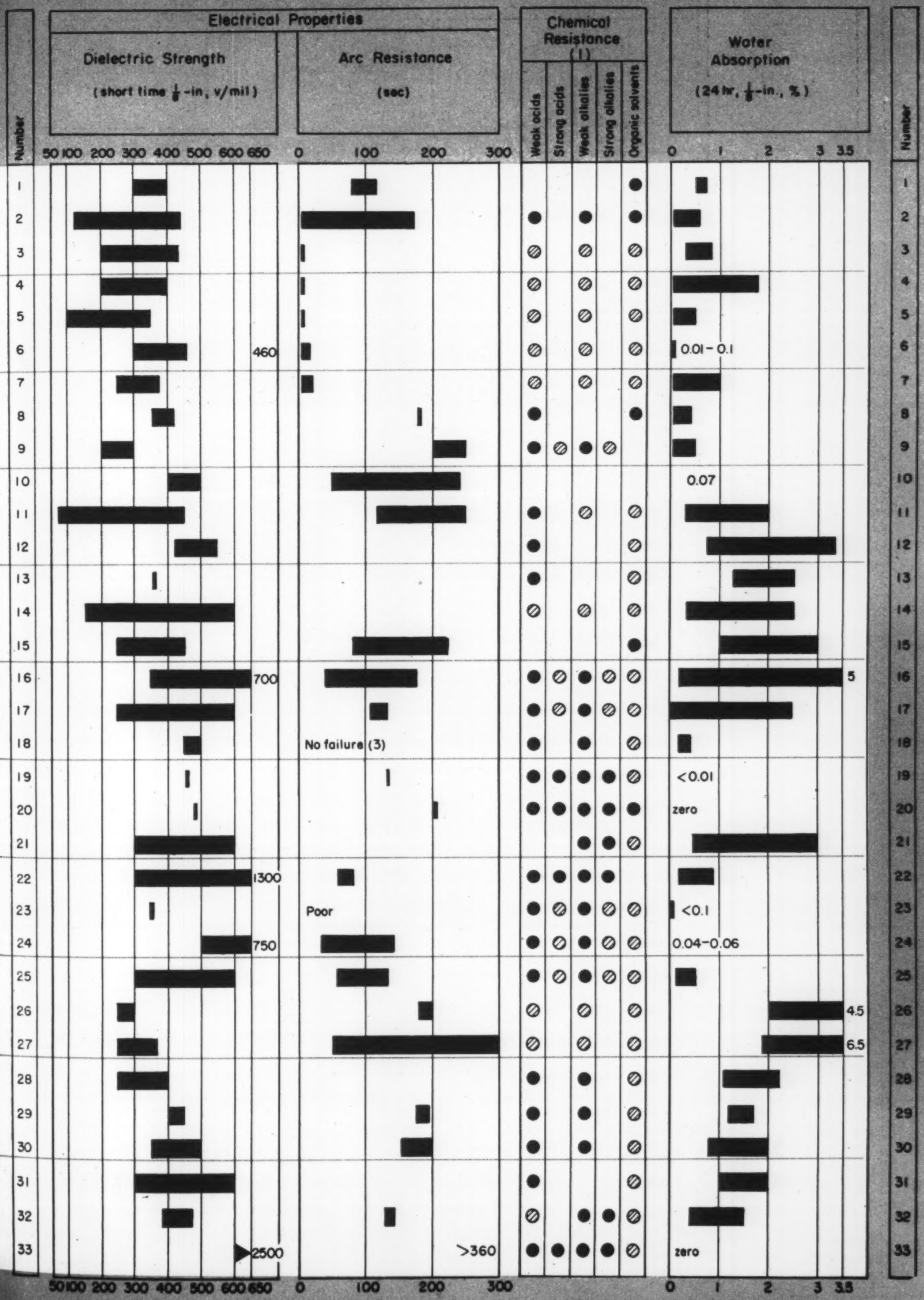
1. Cross-hatched—specific compositions may have good resistance to some chemicals or solvents within group; solid—generally good to excellent resistance.
2. Standard NEMA grades; tensile stresses are lengthwise; compressive stresses are edgewise.
3. Arc ignites gases produced by heat; no carbonized path.

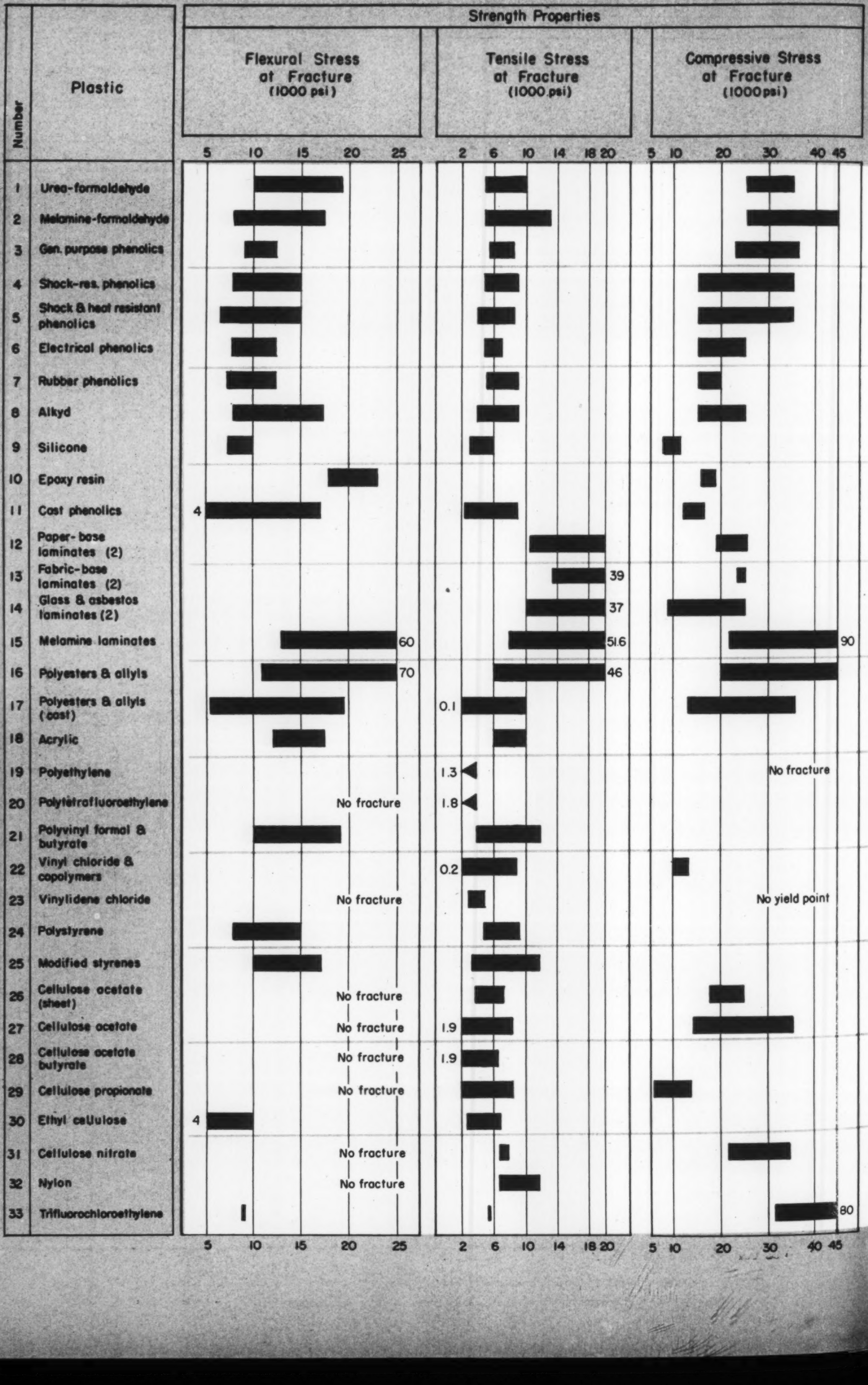


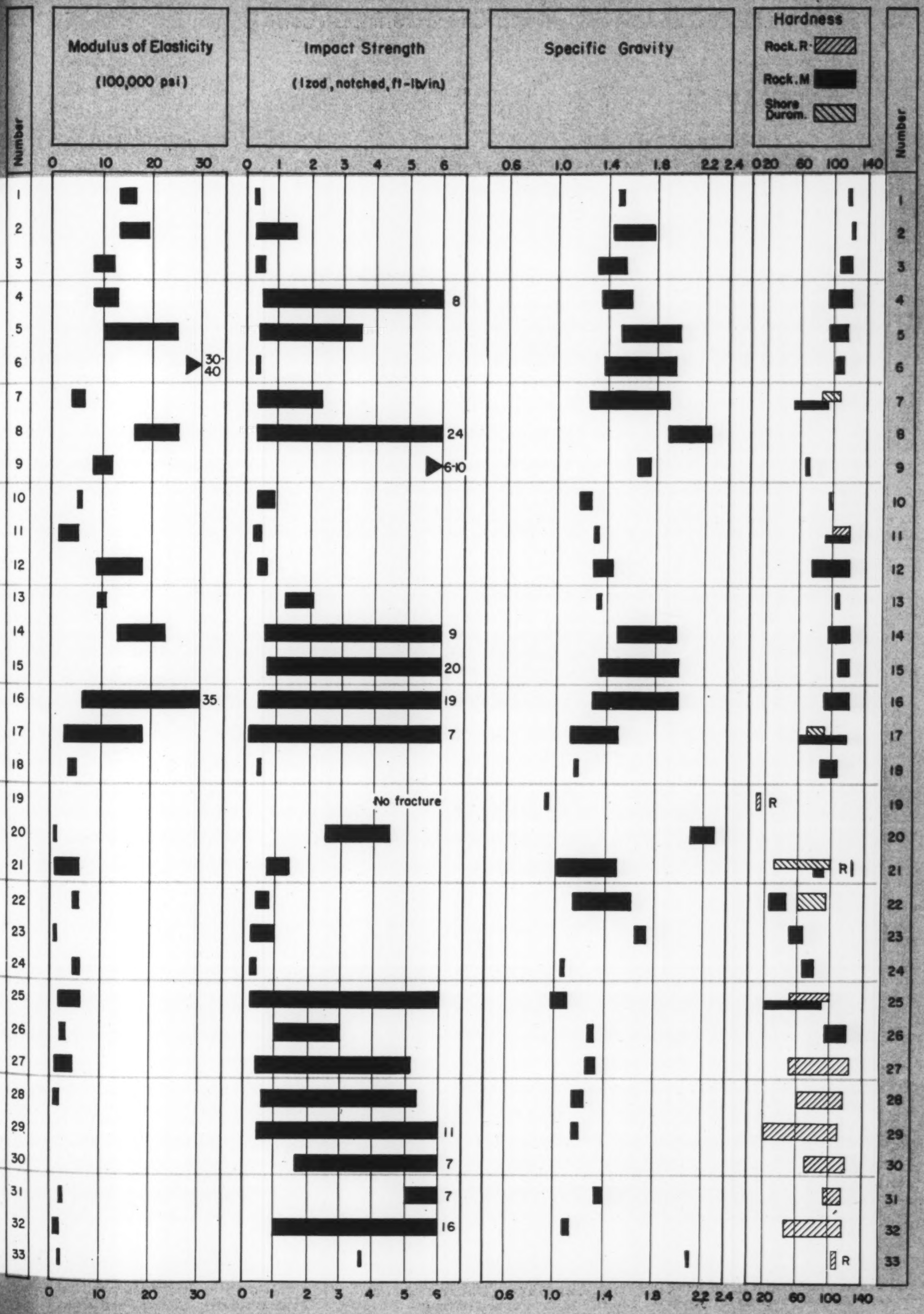
Chemical Resistance (1)

Number	Weak acids	Strong acids	Weak alkalies	Strong alkalies	Organic solvents
1					●
2	●		●		●
3	⊘		⊘		⊘
4	⊘		⊘		⊘
5	⊘		⊘		⊘
6	⊘		⊘		⊘
7	⊘		⊘		⊘
8	●				●
9	●	⊘	●	⊘	
10					
11	●		⊘		⊘
12	●				⊘
13	●				⊘
14	⊘		⊘		⊘
15					●
16	●	⊘	●	⊘	⊘
17	●	⊘	●	⊘	⊘
18	●		●		⊘
19	●	●	●	●	⊘
20	●	●	●	●	●
21			●	●	⊘
22	●	●	●	●	
23	●	⊘	●	⊘	⊘
24	●	⊘	●	⊘	⊘
25	●	⊘	●	⊘	⊘
26	⊘		⊘		⊘
27	⊘		⊘		⊘
28	●		●		⊘
29	●		●		⊘
30	●		●		⊘
31	●				⊘
32	⊘		●	●	⊘
33	●	●	●	●	⊘

4. Special molding equipment necessary; usually supplied as molded blanks for machining or coining to size.

5. Acquires thermosetting properties when combined with thermosetting resins.


Strength Properties
Number
Plastic
Flexural Stress at Fracture (1000 psi)
Tensile Stress at Fracture (1000 psi)
Compressive Stress at Fracture (1000 psi)
5 10 15 20 25
2 6 10 14 18 20
5 10 20 30 40 45
1 Urea-formaldehyde
2 Melamine-formaldehyde
3 Gen. purpose phenolics
4 Shock-res. phenolics
5 Shock & heat resistant phenolics
6 Electrical phenolics
7 Rubber phenolics
8 Alkyd
9 Silicone
10 Epoxy resin
11 Cast phenolics
12 Paper-base laminates (2)
13 Fabric-base laminates (2)
14 Glass & asbestos laminates (2)
15 Melamine laminates
16 Polyesters & allyls
17 Polyesters & allyls (cast)
18 Acrylic
19 Polyethylene
20 Polytetrafluoroethylene
21 Polyvinyl formal & butyrate
22 Vinyl chloride & copolymers
23 Vinylidene chloride
24 Polystyrene
25 Modified styrenes
26 Cellulose acetate (sheet)
27 Cellulose acetate
28 Cellulose acetate butyrate
29 Cellulose propionate
30 Ethyl cellulose
31 Cellulose nitrate
32 Nylon
33 Trifluorochloroethylene
4
39
37
60
51.6
90
70
46
0.1
1.3
No fracture
No fracture
1.8
0.2
No fracture
No yield point
No fracture
No fracture
1.9
No fracture
1.9
No fracture
4
No fracture
No fracture
80
5 10 15 20 25
2 6 10 14 18 20
5 10 20 30 40 45


Number
Modulus of Elasticity
(100,000 psi)
0
10
20
30
Impact Strength
(Izod, notched, ft-lb/in.)
0
1
2
3
4
5
6
Specific Gravity
0.6
1.0
1.4
1.8
2.2
2.4
Hardness
Rock. R
Rock. M
Shore Durom.
0
20
60
100
140
Number
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
8
30-40
24
6-10
9
20
35
19
7
No fracture
R
R
11
7
7
16
R

Plastic Compositions and Characteristics (Cont.)

(*Table continued from Page* 171)

temperature range; inert to most solvents; low moisture permeability and absorption, and excellent electrical properties (electrical grade available but not shown in comparison chart); nontoxic, odorless and tasteless; lower density than any other commercially available nonporous plastic; waxy white, translucent appearance; can be oriented by cold drawing for increased tensile strength.

Typical Uses: Major applications have been packaging, wire and cable insulation, and chemical tank liners.

20.—Polytetrafluoroethylene (Teflon)

Composition: Crystalline linear polymer.

Outstanding Characteristics: Extreme resistance to corrosive agents and solvents—resists even aqua regia without swelling or softening; attacked only by molten alkali metals and fluorine under certain conditions; stable at high temperatures; low power factor and dielectric constant; moldings have high impact strength, but are easily stressed beyond point of maximum recovery; not embrittled by temperatures as low as −100 C; abrasion-resistant, and self-lubricating; light-colored, waxy opaque appearance.

Typical Uses: Gaskets, pipe and tubing for corrosive conditions; machinery for handling sticky compounds such as bread dough, candy, etc.

21.—Polyvinyl Formal and Butyral

Composition: Made by hydrolysis of polyvinyl acetate and reaction with corresponding aldehyde; plasticized or unplasticized.

Outstanding Characteristics: Combination of toughness with dimensional stability; can be plasticized to elastomers, or made thermosetting by addition of other resins with consequent dimensional stability.

Typical Uses: Hose and tubing; rubber-like parts; largely used for safety glass interlayers, coatings, film and sheeting.

22.—Vinyl Chloride and Copolymers

Composition: Polyvinyl chloride; vinyl chloride copolymers with vinyl acetate and vinylidene chloride, in plasticized compositions; elastomeric varieties are plasticized with high-boiling liquids, soft resins or nitrile rubber.

Outstandng Characteristics: Excellent dielectric properties and flexibility; good aging properties; resistant to oil and water; durable and abrasion resistant; rigid forms have good dimensional stability; translucent and opaque colors; rigid sheet can be transparent; has definite temperature limitations.

Typical Uses: Floor coverings; aircraft plotting and navigating instruments.

23.—Vinylidene Choride (Saran)

Composition: Monomeric liquid vinylidene chloride polymerized to yield resin.

Outstanding Characteristics: Range from flexible materials with low softening points to hard, tough, practically insoluble materials; practically impervious to water with high resistance to water vapor transmission; dimensionally stable even after boiling in water; resists most inorganic chemicals and organic solvents; good mechanical properties; not recommended for high-speed impact, shock resistance, or flexibility at subfreezing temperatures; unusually good weld strength.

Typical Uses: Tubing; rigid pipe; screening.

24, 25.—Polystyrene and Modified Styrenes

Composition: Polystyrene—at least 95 per cent styrene monomer with no more than 5 per cent of other monomer, lubricant and colorant; modified—50 to 95 per cent styrene monomer, with usual range of 10 to 25 per cent organic nitrile rubber such as acrylonitrile.

Outstanding Characteristics: Polystyrene—low weight, excellent dimensional stability, exceptional electrical properties, stability at low temperatures, brilliant clarity in transparent forms with ability to "pipe" light around corners, tasteless and odorless, negligible water absorption, good corrosive-chemical resistance; modified types—improved heat and chemical resistance at expense of moldability, improved shock resistance (with preservation of dimensional stability) with slight reduction in heat resistance, hardness, electrical properties, and other strength properties; polystyrene can be transparent, translucent or opaque in wide color range; modified types are limited in colors and transparency.

Typical Uses: Polystyrene—refrigerator parts, fluorescent light fixtures, rigid containers, light machine housings, nameplates, radio cabinets, clock and camera cases, knobs; modified styrenes—battery cases, thermostat housings, drafting instruments, sight glasses, plastic pipe and fittings, large-area refrigerator parts.

26, 27, 28.—Cellulose Acetate and Cellulose Acetate Butyrate

Composition: Combined with plasticizers, dyes and pigments.

Outstanding Characteristics: Transparent; tough, with relatively high impact strength; easy to fabricate; available in any shade of color or degree of translucence including clear transparents, pearls and variegated colors; limited resistance to cold flow with some dimensional change; molding compositions are recommended only for relatively low loads, and where slight shrinkage on aging can be tolerated.

Typical Uses: Machine guards; rigid containers; automotive and radio knobs; electrical parts; telephones; steering wheels; radio housings.

29.—Cellulose Propionate

Composition: Combined with plasticizers, pigments and dyes.

Outstanding Characteristics: Tough; high impact strength; outstanding machinability and moldability with brilliant surface finish under short cycle; cold-flow resistance is limited—slight dimensional changes must be expected and applications should be for low loads; any shade of color or degree of translucence.

Typical Uses: Telephones; automotive escutcheons and bezels; knobs and pulls; housings.

30.—Ethyl Cellulose

Composition: Combined with plasticizers, pigments and dyes.

Outstanding Characteristics: High impact strength and toughness even at low temperatures; retains dimensional stability under abnormal heat and moisture conditions; recommended for low loads since resistance to deformation under load is limited; transparent, opaque and variegated colors, although crystals, lightly tinted transparents and translucent pastels are generally not available; hard extrusion grade (not covered in comparison chart) is also available with higher hardness, heat distortion temperature, and better machinability and finishing properties.

Typical Uses: Radio housings; vacuum cleaner parts; electrical parts; knobs.

31.—Cellulose Nitrate

Composition: Combined with plasticizers (usually camphor), pigments and dyes.

Outstanding Characteristics: Excellent toughness; easily fabricated; resilient; dimensionally stable; chief disadvantage is high flammability and degradation upon exposure to sunlight; any shade of color or degree of translucence including transparents, pearls and variegated colors.

Typical Uses: Handles; drawing instruments; clock cases; battery cases; sight gages.

32.—Nylon

Composition: Synthetic fiber-forming polymeric amides (polyamides) having a protein-like chemical structure.

Outstanding Characteristics: Good strength and toughness; good flow properties, making possible tough thin-section moldings; wear-resistant; self-lubrication properties; relatively high temperature and chemical resistance.

Typical Uses: Gears; cams; small bearings; electrical parts; containers.

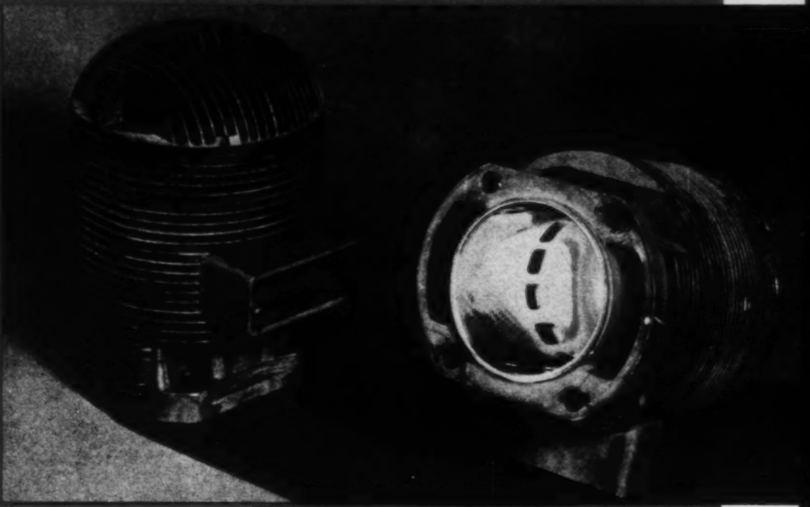
33.—Trifluorochloroethylene (Kel-F)

Composition: Unfilled or with solid fillers and coloring agents.

Outstanding Characteristics: High resistance to strong alkalies and acids, including aqua regia, and most organic solvents; slightly swelled and plasticized by highly halogenated materials and some aromatics; satisfactory properties down to −320 F; very high electrical resistance; resists wetting; mechanical properties can be varied by heat treatment.

Typical Uses: Valve seats and packing; pump packing and diaphragms; pipe, tubing and gaskets; electrical parts.

finishes for aluminum



Die-cast aluminum cylinders produced by McCulloch Motors Corp. have hard chrome plated bores for higher surface hardness and increased wear resistance.

By R. V. VANDEN BERG
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Aluminum Company of America, New Kensington, Pa.

ALUMINUM in its natural form has a pleasing appearance and good resistance to corrosion. For many applications, however, it is desirable to change its appearance, increase surface hardness, or change the natural surface to make it appropriate. Aluminum responds to a wide variety of finishing processes; its versatility in this respect is outstanding.

Many finishing systems are available which produce attractive decorative effects; however, this discussion will in general be confined to finishing systems for functional applications. These include mechanical finishing, electrolytic oxidation, electrobrightening, electroplating, chemical coating, and painting, lacquering or enameling. Sometimes, of course, these systems must be used in combination in order to produce the finish most practical for the application.

MECHANICAL FINISHES: In general, any discussion regarding the finishing of aluminum begins with mechanical finishing, since some mechanical finishing is generally required on the surface as the basis for subsequent finishing procedures. Mechanical finishing imparts a certain texture to the surface, important for many applications because it results in a desirable appearance for decorative reasons. On the other hand, mechanical finishing is also important from a functional standpoint, since the surface may be made smooth or rough depending upon the requirements of the application.

Air-abrasive blasting with or without water is often used to obtain a light-diffusing surface. The surface texture produced by this method might also be used as a base for painting or electroplating. Although a rough surface is not necessary for plating or electroplating, to obtain the best plating adhesion on such parts as castings, abrasive blasting may be the most practical procedure for cleaning the surface. Modern electroplating procedures for aluminum alloys do not require a rough surface to obtain maximum adhesion of electrodeposited coatings, but some applications require surface roughness to "key" the electroplated coatings.

Distortion of thin sections is a disadvantage of the blasting method, and care must be taken with operating conditions to keep distortion at a minimum.

Four of the many types of finishes which can be applied to aluminum, applied in this case to pistons to prevent scuffing and rubbing abrasion. At upper left is an oxide coating produced by chemical immersion and impregnated with graphite; upper right, an anodic-oxide coating; lower left, a brass coating by the immersion process; and lower right, a tin-immersion coating.

Barrel burnishing, particularly the type which incorporates abrasive chips in the mixture, is an important mechanical finishing procedure. This low-cost method is ideally suited for mass production of small cast, forged or formed-sheet parts to remove minor surface irregularities.

Polishing to smooth the surface is perhaps the most fundamental mechanical finishing operation. Aluminum is considered a soft metal; therefore, when polishing aluminum, care must be taken to use proper lubrication on the wheels or belts so that loading of the abrasive is avoided. Excessive loading will cause overheating of the surface and tears.

ELECTROCHEMICAL TREATMENTS: Although electrolytic oxidation, electrobrightening and electroplating could be grouped in the general category of electrochemical treatments, certain differences make it advisable to discuss them as separate, distinct treatments. Electrolytic oxidation and electrobrightening, sometimes referred to as electropolishing, are both anodic procedures but the results from these processes are decidedly different. Electrolytic oxidation produces a coating on the surface with varying characteristics depending upon operating conditions. Electrobrightening, as the name implies, brightens or smooths the surface by removing varying amounts of metal, depending upon the particular process employed. In electroplating, a metallic layer is formed on the surface—the same as in electroplating other metals. Although both electrolytic oxidation and electroplating form coatings, in the case of electrolytic oxidation the coating is integral with the surface and is essentially aluminum oxide.

CHEMICAL TREATMENTS: Chemical treatments rely on the chemical action of the solution to remove metal, convert the surface into a coating or place a metallic coating on the surface. All etches for aluminum and its alloys are included in this category; these etches are numerous and cover a wide range of applications. By using chemical methods alone, it is possible to produce oxide and phosphate type coatings which have excellent resistance to corrosion. The good film forming characteristics of aluminum make these types of treatments possible. The chemical activity of aluminum and its alloys is also responsible for the immersion type coatings which have important commercial applications.

FINISHES: Paints, lacquers and enamels, including vitreous enamels, should also be considered for their functional effects. Although in many commercial applications these systems are used for their eye-appeal, they also are used for protection against corrosion for severe exposure conditions. Vitreous enamels, because of their hardness, heat and mechanical shock resistance, and dielectric properties, offer possibilities in applications requiring these characteristics.

Anodic Oxidation: By making aluminum or its alloys the anode in a suitable electrolyte under controlled conditions of voltage, current density and temperature, a surface coating is formed which is essentially aluminum oxide. This oxide coating, typified by the Alcoa Alumilite finish, is the result of electrochemical oxidation of the aluminum and will not chip or peel from the surface. Generally, any chemical that attacks the coating will also attack the underlying aluminum. A solution composed of chromic and phosphoric acids, however, dissolves the coating without attacking the base metal.

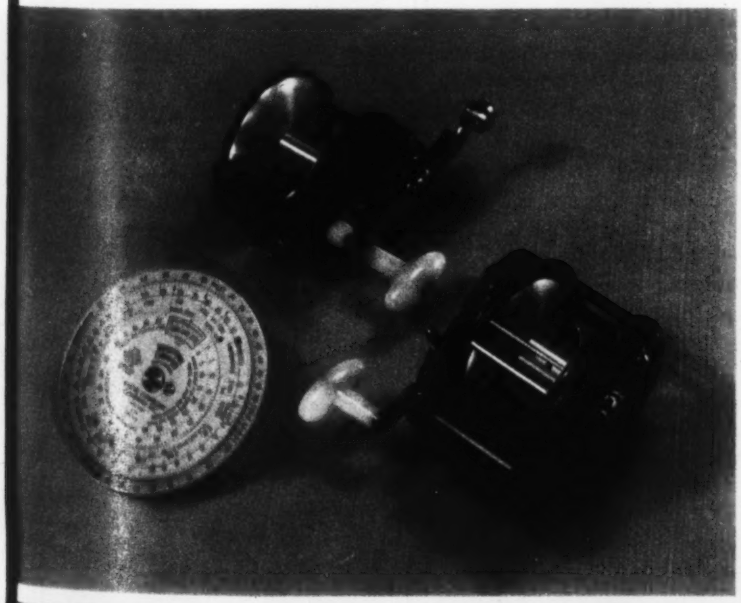
This electrolytic-oxide process is applicable to all aluminum alloys, but structure and color of the resulting oxide film varies with alloy and temper. Alumilite coatings on high-purity aluminum are continuous and transparent. As alloy constituent increases, the coatings become more opaque. Silicon is particularly effective in changing the color of the coating; since silicon is not appreciably dissolved or oxidized by the anodic treatment, it remains in the coating as elemental silicon. Presence of silicon causes the coating to have a gray, gun-metal color. As most aluminum alloy castings contain varying amounts of silicon, anodic-oxide coatings on castings are rather dark in color; some casting alloys, however, produce uniform and attractive coatings. Weld fillets made with aluminum-silicon alloy wire also have a dark appearance after finishing.

An electrolytic-oxide coating, as formed, has a cellular structure composed of a wall of oxide surrounding pores or groups of pores. The portion of the oxide nearest the outer surface is sponge-like in form because of the solvent action of the electrolyte. This structure, and the mordanting action of the film, are valuable characteristics which can be used to advantage in coloring the coating by means of water soluble dyestuffs or pigments. The colors produced are unique; the luster of the underlying metal gives a metallic sheen which is very attractive for decorative applications. The finish reproduces the texture of the surface on which it is formed, and if the silvery metallic appearance is desired, a sealing treatment is used to close the pores and make the coating stain and corrosion-resistant.

Special procedures enable selective dyeing of the surface to produce permanent identification used commercially for name plates. When protection is the main consideration, special sealing techniques are used to incorporate corrosion inhibitors into the coating. The coloring treatment often includes a corrosion inhibitor to produce a colored finish with excellent resistance to corrosion. Such a system is employed when the coating is used as a base for protective paints or enamels, especially with black coatings in combination with black enamels for instruments.

Inasmuch as aluminum oxide or alumina is a hard substance, the finish is resistant to abrasion. By variations in the procedure, coatings with a wide range of hardness may be produced.

One of the first commercial applications of Alumilite



Anodic-oxide coating produced by an electrochemical process is used for salt-spray resistance on the fishing reels; a second advantage is that the coating can be brilliantly colored. A similar Alumilite finish provides contrast between graduations and background of the navigational computer.

High corrosion resistance is a feature of anodic coatings formed in chromic acid electrolytes. Revolver frame, rifle receiver and gunsight frame are dyed black to provide a surface of low reflectivity. Function of the oxide coating on the hydraulic brake cylinder is protection from corrosion and wear.

finishes was on aluminum-alloy automotive pistons. During initial use the coating glazes, thus minimizing wear on the piston so that the "running in" period is shortened. The ability of this finish to resist "cold scuffing" proves to be another desirable characteristic.

HARD ANODIC COATINGS: Recently, procedures have been developed to produce oxide coatings of greater thickness and increased compactness—of which Alumilite 225, 226, 725 and 726, and Martin Hard Coatings (MHC) are an example. Because of their substantial thickness (0.001 to 0.005-inch) and denser structure, these hard coatings are able to support greater loads and overcome to a great extent the deficiency of the thinner oxide coatings with reference to scratching or indentation abrasion; also, because of their extra thickness and greater compactness, these coatings are highly resistant to corrosion and have high dielectric strength. Density of hard coatings is compared with that of standard anodic-oxide coatings in ***Figs.*** 1 and 2. Although the heavy coatings are many times more resistant to abrasion than the thinner coatings, some care must be taken to avoid highly localized loading.

The hard anodic coatings for aluminum alloys have been of considerable interest to the aircraft industry, where a light metal with a hard, wear-resistant finish offers a valuable replacement for parts produced from heavier metals of higher inherent hardness. Aluminum alloys with hard oxide coatings are now being used or considered for gears, pinions, bearing races, gun blast tubes, slides, various pistons, helicopter blade edges, and numerous other miscellaneous aircraft applications. These coatings also offer possibilities in applications where aluminum alloys are subjected to the erosive influences of hot gasses or liquids. Hard coatings are now being applied to high velocity pumps and blower impellers to minimize erosion.

Better results are obtained for applications involving the rubbing type of abrasion if the coatings are honed to a high degree of surface smoothness, and some surface lubricant such as molybdenum disulphide or various graphite compositions is applied to the coating.

Resistance to abrasion of hard coatings has been compared with that of coatings ordinarily employed for decorative or protective purposes by two different abrasion tests. One of these tests established the resistance to wear by rubbing; the other determined the ability of these coatings to resist erosion from a grit blast.

The results of abrasion tests of this type indicate that these hard oxide coatings are much more resistant to wear and abrasion than thinner oxide coatings ordinarily used. In general, the improvement in resistance to the rubbing type of abrasion is much greater than that for the blast type of abrasion. Glenn L. Martin Co. has reported that after 50,000 cycles on the Taber Abraser a MHC coating 2 mils in thickness showed only about half as much wear as casehardened steel. In the grit-blast abrasion test, resistance to abrasion of the hard coating is about double that for an ordinary anodic oxide coating of the same thickness. The results of grit-blast abrasion tests on ordinary and hard oxide coatings on a number of typical wrought aluminum alloys are shown in detail in TABLE 1.

The type of alloy being coated has a definite effect on the characteristics of these hard coatings. Care must be taken in applying such coatings to casting alloys, since they usually contain appreciable amounts of silicon, and alloys having a silicon content of 7 per cent or over do not respond satisfactorily to the treatment. Alloys containing high percentages of copper and silicon also will not produce dense coatings of uniform thickness. Coatings will be formed on wrought alloys, such as 11S, 14S, 17S and 24S, but operating conditions are more critical, and the coatings are not as good as those formed on alloys such as 2S, 3S, 52S, 61S or 75S.

Because aluminum oxide is a good dielectric, the oxide finish has sometimes been used as an insulating medium on aluminum and its alloys. An anodic coating of 0.0005-inch thickness may have voltage breakdown values as high as 600 volts. Unfortunately, however, the minimum breakdown voltage may be 200 to 300 because of weak spots. For some classes of work, the voltage breakdown test can serve as a quick test to determine approximate thickness of the coating. Because of a number of variables affecting breakdown voltage other than thickness, it is not practical to use this method generally to determine thickness of coatings with unknown characteristics.

An important characteristic of the anodic coating as an insulation medium is its stability when heated; it does not char or give off gas as do organic insulating materials. Cost of application, however, is one factor that limits its use. Anodic coatings produced from boric acid electrolytes have excellent dielectric properties and are used commercially on condenser foil and plates.

CHROMIC-ACID ANODIC COATINGS: The anodic finish offers substantial protection against corrosion, especially those coatings which have been sealed by hot dichromate solutions. These corrosion-resistant coatings meet the requirements of Specification AN-QQ-A-696a. Anodic treatment in chromic electrolytes produces coatings which are thinner than those produced in sulfuric acid electrolytes, but they have exceptional resistance to corrosion and also will meet the requirements of AN-QQ-A-696a.

Anodic coatings formed in chromic acid electrolytes have little or no decorative applications. Although attractive pastel colors are possible, very little commercial application is possible because the coatings have low resistance to abrasion. Black anodic coatings formed in chromic acid are used for military applications. These coatings are somewhat thicker than average in order to respond to the dyeing treatment used to produce the black coatings. Such coatings have the advantage of a black surface of low reflectivity combined with high resistance to corrosion.

Present military specifications require anodic coatings applied in chromic acid for applications where possibilities of entrapment of electrolyte exist in structures assembled by rivets, screws, spot or seam welding. Many applications requiring increased resistance to corrosion for parts subjected to high vibratory stresses require anodic coatings of this type because the coatings are thinner than those formed in sulfuric acid electrolytes. These thinner coatings are particularly useful on aluminum alloys sensitive to fatigue.

Anodic treatment of certain aluminum alloy castings by the chromic acid process is not advisable. Because of their high alloy content, these alloys do not form coatings of appreciable thickness. In most cases anodic dissolution of the metal takes place. Anodic coatings are produced from a wide variety of electrolytes; however, the processes discussed are generally the ones in greatest commercial applications.

Electrobrightening Processes: Several electrobrightening processes are used to obtain maximum surface brightness. These processes remove a thin surface film of metal together with any contaminating substances such as oxide, buffing compound, alloy constituent, etc. These brightening treatments tend to smooth the surface, but do not remove deep scratches and pits. Electrobrightening treatments, therefore, are not substitutes for buffing. They are, however, used to advantage after buffing and before a decorative anodic coating is applied to obtain surfaces having maximum brightness. Some electrobrightening treatments will remove burrs and other minor irregularities from the surface. This treatment requires high anodic current densities and is somewhat more expensive to operate.

A typical commercial application of electrobrightening is the Alzak process, which consists of an anodic treatment in a fluoboric acid electrolyte. An Alumilite finish is finally applied to protect the surface of aluminum reflectors. Reflectors made by this process are characterized by a combination of permanence and high reflectivity. Either specular or diffuse reflecting surfaces can be produced. Specular reflectors are produced from special sheet products. For maximum resistance to corrosion and abrasion, a relatively heavy coating is recommended to protect the surface. Heavier coatings, however, lower the reflectivity. Even though the aluminum oxide coating is clear and apparently transparent, it absorbs appreciable amounts of radiant energy.

As might be expected, reflectivity of these reflectors varies both with the type of surface and with spectral wave length of the light. Specular Alzak surfaces reflect a maximum of 80 to 85 per cent of white light. With diffusing reflectors, reflectivity of 75 to 80 per cent of white light is possible. In the far infrared range, reflectivity rises to above 90 per cent, while in the ultraviolet range the finish has a reflectivity superior to that of commercial metallic reflectors.

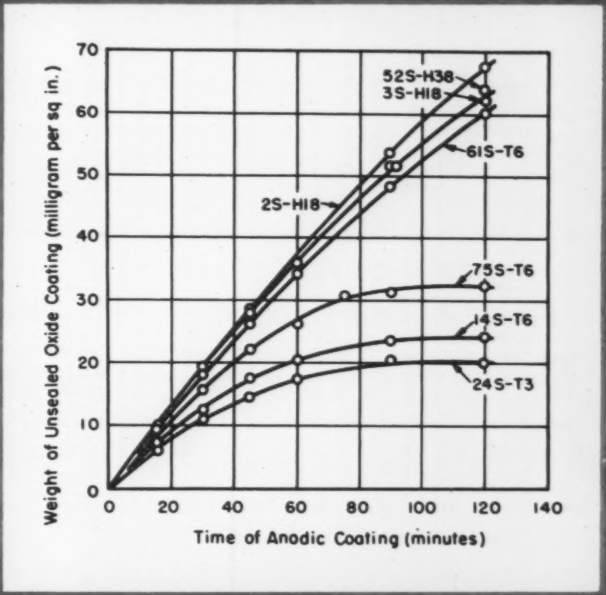


Fig. 1—Weight of anodic - oxide (Alumilite) coating produced on aluminum alloys for various processing times

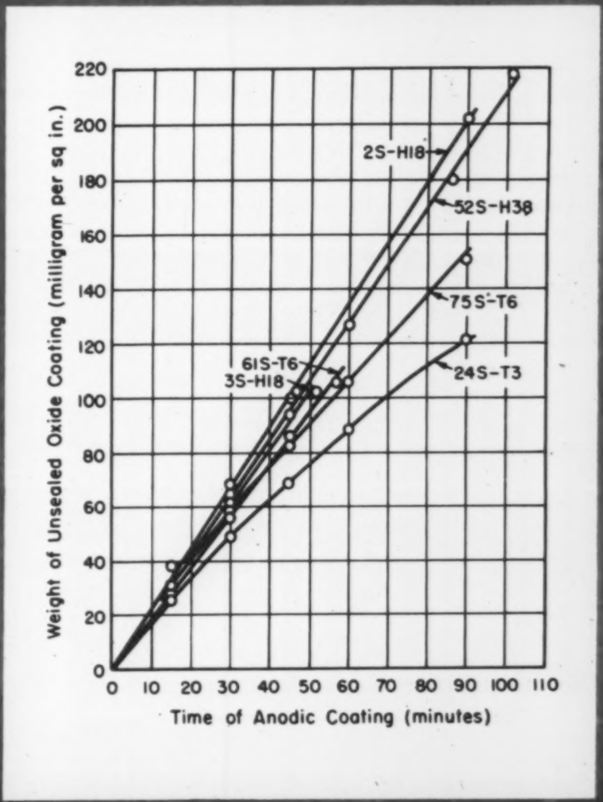


Fig. 2—Ability of hard anodic-oxide processes (Alumilite Hard Coatings) to build up thick coatings is demonstrated by comparison with *Fig.* 1

Electroplating Processes: Practical commercial methods are now available for electroplating aluminum and its alloys. These include:

1. Deposition over a surface roughened by chemical etching.
2. Anodic oxidation of the surface and modification of the film to "key" the deposit.
3. Chemical oxidation of the surface as a surface preparation.
4. Surface pretreatment consisting of immersion dip in sodium zincate solution to produce a zinc film.

Of all these methods, the surface pretreatment method consisting of immersion in the sodium zincate solution, commonly referred to as the "zinc immersion" process, is considered to be the most generally satisfactory and practical. Generally, the other methods are too complicated and the conditions are too critical for commercial use.

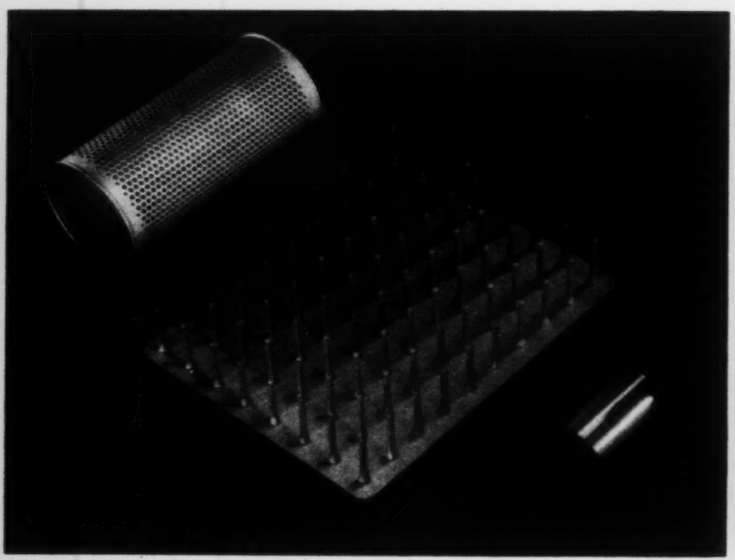
Recent improvements in the zinc immersion process have resulted in an effective method to produce electroplated deposits with good adhesion. The flow diagram in *Fig.* 3 contains the essential steps for electroplating aluminum alloys. In order to obtain maximum adhesion, a modified Rochelle-cyanide-copper strike solution is used over the zinc layer. Once the copper strike layer has been applied, other metals such as nickel, brass, silver, zinc, cadmium, hard chrome and tin may be applied.

Brass, cadmium, nickel, chromium and silver may be applied directly over the zinc immersion layer. Hard chrome and nickel have also been applied directly over the zinc layer, but conditions are critical and this procedure does not always produce good uniform adhesion. Excellent results have been obtained with heavy hard chrome deposits plating in a high-temperature bath over the copper deposit from the Rochelle-cyanide-copper strike solution. If silver is applied directly over zinc, the use of two low-concentration silver-cyanide baths is recommended before plating in the standard cyanide bath.

To furnish eye-appeal, decorative bright chrome systems are employed for many purposes. Hard chromium plating based upon the zinc immersion process is being used to increase the surface hardness and wear resistance of aluminum alloys. An excellent example of hard chromium for this application is the cylinder bores of small lightweight two-cycle gasoline engines. These die-cast cylinders are chromium plated in the bores to increase output of the small portable engines.

Silver increases surface electrical conductivity, and present commercial practice involves the application of silver plate to aluminum bus bar connections and miscellaneous electronic instruments to reduce contact resistance and increase conductivity of high frequency currents.

Copper plating permits the use of standard soft soldering methods for some joining purposes. Brass is applied for rubber bonding or decorative effects. Zinc prevents seizing of surfaces, and aluminum slide fastener wires have been plated with either zinc, cadmium or nickel to decrease friction and produce smoother operation. Tin or lead-tin alloys are deposited to obtain better frictional properties for certain bearing applications. Tin or cadmium is applied



A hard finish is needed in high-speed textile machinery equipment for protection against abrasion, gained in the case of this spin spool, quill board and bobbin by an electrochemical oxide coating.

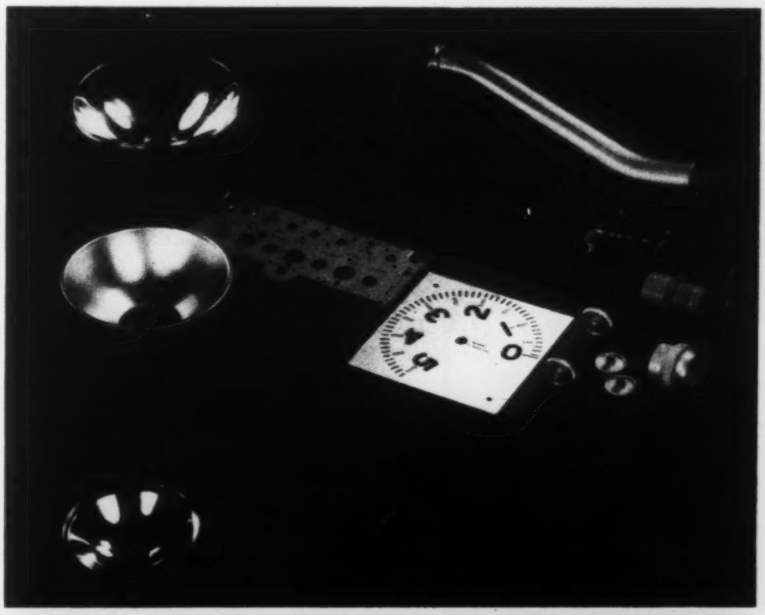
Staining and abrasion is prevented on this meat-slicer housing by an anodic-oxide coating over satin-finish aluminum. The underlying surface finish of the metal is seen through the coating.

for applications requiring a combination of good solderability and conductivity.

Aluminum alloy sheet is used commercially for plates for selenium rectifiers. Selenium must be bonded to the surface after a preliminary coating of nickel is applied in order to obtain the properties necessary for the application. For this application, the zinc film prior to the plating cannot be used; therefore, the surface is roughened either mechanically or with an etch to produce the necessary "keys" in the surface to hold the nickel. Selenium is then applied to the nickel by pressure bonding or vaporizing.

Chemical Processes: Various chemical treatments may be used to produce surface effects not possible with mechanical procedures. The most important objectives of chemical treatments are:

1. Improving the appearance of a product; or obtaining either a bright reflecting surface, or a rough or smooth diffusing surface.
2. Removing a surface layer of metal to eliminate dirt, grease, roll coating, annealing or heat treating film, buffing compounds and welding flux.
3. Cleaning without roughening or otherwise changing the surface.
4. Removing oxide or chemical coatings.
5. Producing a surface with increased resistance to corrosion and providing good adhesion for paints and enamels.
6. Producing a metallic coating for better frictional properties.



An electrobrightening process produces either specular or diffuse reflectors, which are protected by an oxide coating. A dichromate-sealed anodic-oxide coating, with a characteristic yellow color, provides excellent corrosion resistance on aluminum gears and instrument panels. Other control panels, and the colored tubular aircraft fitting, have standard electrolytic-oxide coatings, while the gun and instrument parts are chromic-acid anodic-oxide coated.

For exceptional abrasion and erosion, a relatively new series of heavier anodic-oxide coatings has been produced. On the gun-blast tube and the impeller, an Alumilite coating protects against erosion. On the aluminum orthopedic brace, a heavy Martin Hard Coating prevents excessive abrasion.

Bright Dip Process: The bright dip process, a recent development of which the Alcoa R5 bright dip is an example, gives a smooth, bright surface on a variety of aluminum alloy products. It produces bright finishes on most wrought aluminum alloys; in general, it is not recommended for casting alloys because they contain appreciable amounts of silicon. Some casting alloys contain little or no silicon, however, and such alloys can be bright dipped successfully. Present commercial applications of the bright dip are limited to decorative applications. The one outstanding exception is to prepare Xerographic plates for selenium films. In this application, the bright dip produces a smooth uniform surface of low electrical resistance necessary for the plates used in this unique printing process.

The bright dip process is similar to electrobrightening treatments and produces surfaces with comparable reflectivity. Both electrobrightening and bright dip pretreatment help to produce a brighter anodic oxide finish by removing embedded buffing compounds which would contaminate the oxide coating and detract from its transparency.

Frosted Finishes and Etching: Frosted finish for aluminum alloys has a very attractive appearance. This finish is used on small and intricate items or large flat surfaces not adapted to mechanical methods of finishing. The frosted or matte effect results from an etching action which produces a large number of extremely small pits in the surface, thus accounting for the light-diffusing characteristics. Since a surface of this type will finger-print or stain rather easily, an oxide coating or a coat of transparent lacquer should be applied for protection. The frosted finish is often used in conjunction with the anodic oxide finish for refrigerator trays, shelves, pans and moldings.

Alkaline solutions are generally used to etch aluminum alloys. There are many varieties, but generally caustic soda solutions of various concentrations are commonly used. The effect is to remove a limited amount of grease or oily film and produce a matte surface. An etch in an alkaline solution is used to produce the surface desired for aluminum reflectors of the diffusing type.

Alkaline solutions are also widely used for cleaning aluminum surfaces. For instance, if 1 ounce of sodium disilicate is added per gallon of 3 per cent soda-ash trisodium phosphate solution, a cleaner is obtained which will not attack aluminum alloys. Another satisfactory method of cleaning aluminum alloys consists of cathodic cleaning in dilute solutions of caustic soda or sodium silicate. Cleaners containing silicates should not be used prior to oxide treatments unless they are followed by a dip in strong nitric acid to remove the interfering film formed by the silicate.

Although alkaline solutions accomplish many of the objectives in surface conditioning aluminum products, treatments in acid solutions are sometimes more desirable. Acid treatments may be used to produce a variety of frosted or matte finishes on aluminum alloys. They are also used to remove undesirable annealing or heat-treating films, buffing compounds and welding flux from the surface. Generally, mixtures of nitric acid and hydrofluoric acid are used to produce various types of frosted finishes on aluminum alloys. A nitric-hydrofluoric acid or sodium acid sulfate-chromate mixture is used to prepare aluminum alloys such as Alclad 24S for spot welding.

Table 1—Grit-Blast Wear of Oxide Coatings

Alloy	Type of Coating*	Coating Thickness (mil)	Abrasive to Wear Through Coating† (gm)	Abrasive per Unit Thickness (gm/mil)
2S-H18	Alumilite 204	0.47	35	75
	Alumilite 215	0.90	88	98
	Alumilite Hard Coating 226	2.24	387	173
	Martin Hard Coating	2.77	405	146
3S-H18	Alumilite 204	0.53	33	62
	Alumilite 215	0.95	94	99
	Alumilite Hard Coating 226	2.33	368	158
61S-T6	Alumilite 204	0.46	41	89
	Alumilite 215	0.88	90	102
	Alumilite Hard Coating 226	2.15	364	169
	Martin Hard Coating	2.31	390	169
75S-T6	Alumilite 204	0.45	46	102
	Alumilite 215	0.90	76	84
	Alumilite Hard Coating 226	2.13	357	168
24S-T3	Alumilite 204	0.41	22	54
	Alumilite 215	0.78	36	46
	Alumilite Hard Coating 226	2.10	142	68
	Martin Hard Coating	2.48	163	66

*All coatings unsealed. †180-grit emery at 5 psi through 11/64-inch diameter orifice.

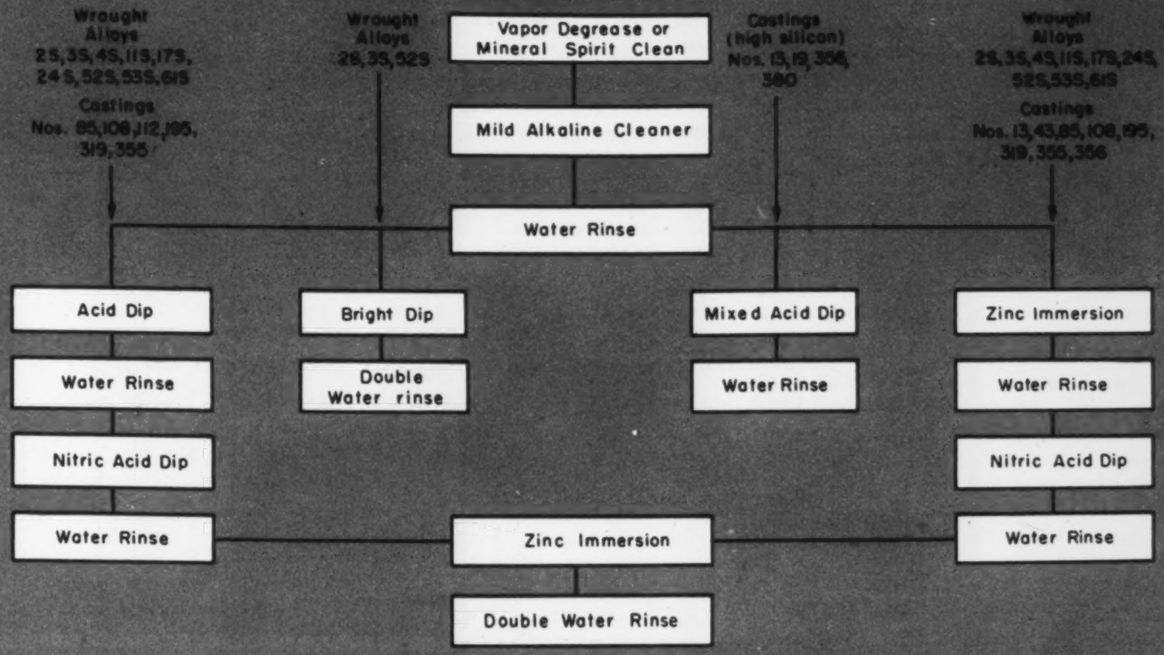

Wrought Alloys 2S,3S,4S,11S,17S, 24S,52S,53S,61S
Castings Nos. 85,108,112,195, 319,355
Wrought Alloys 2S,3S,52S
Vapor Degrease or Mineral Spirit Clean
Mild Alkaline Cleaner
Water Rinse
Castings (high silicon) Nos. 13,19,356, 380
Wrought Alloys 2S,3S,4S,11S,17S,24S, 52S,53S,61S
Castings Nos. 13,43,85,108,195, 319,355,356
Acid Dip
Water Rinse
Nitric Acid Dip
Water Rinse
Bright Dip
Double Water rinse
Mixed Acid Dip
Water Rinse
Zinc Immersion
Water Rinse
Nitric Acid Dip
Water Rinse
Zinc Immersion
Double Water Rinse

Fig. 3—Pretreatment of aluminum alloys by the zinc immersion process for electroplating

Extensive use is being made of etching in the manufacture of aluminum nameplates and dials. Designs can be etched readily by a fairly simple procedure. Areas to be protected from the etching solution must first be covered with a "resist" to withstand the action of the solution. To form the resist, the desired design is applied to the aluminum surfaces by printing or silk screen. Generally, etching solutions for this type of work contain appreciable amounts of hydrochloric acid. After the surface is etched to the desired depth, the resist is removed with toluol and, if desired, the background may be colored with (1) an anodic oxide coating, (2) black nickel, (3) enamel, or (4) ink.

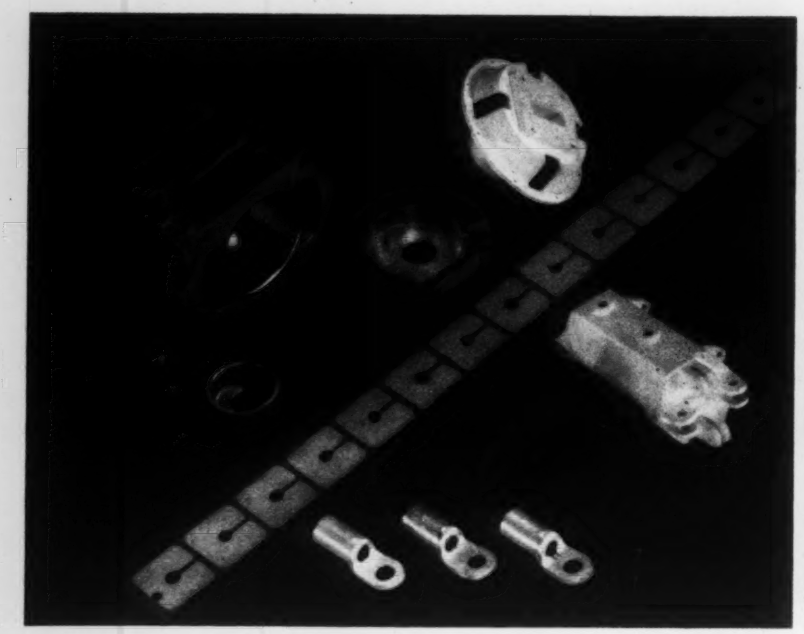
CHEMICAL OXIDE COATINGS: One series of chemical finishes for aluminum alloys, identified by the tradename Alrok, produces an oxide coating less resistant to abrasion and corrosion than those produced by anodic oxidation processes. Although these chemical-oxide finishes have little decorative value, they possess appreciable resistance to corrosion and serve as an excellent base for paint. They are generally lower in cost than electrochemical processes and are especially adapted to the bulk treatment of small parts.

The coatings differ in color and appearance depending upon the process used and aluminum alloy coated. These finishes are applied in an alkaline solution which produces a color varying from gray to greenish gray. A hot dichromate sealing treatment is employed when resistance to corrosion is required, which changes the color to a yellowish green. Generally, the coatings have a glossy appearance, but are dull if the surface has been etched before application of the coating. Although some of the coatings may be dyed, the colored finishes lack the depth of color obtainable with most anodic coatings.

PHOSPHATE COATINGS: A wide variety of proprietary chemical treatments are commercially available for producing phosphate films on the surface of aluminum alloys. Most of the treatments meet the requirements of Specification MIL-C-5541. These films are usually used as a base for paint, lacquer or enamel.

IMMERSION COATINGS OF METAL: Applications involving wear or a rubbing type of abrasion often require deposition of softer metals than chromium. Tin has natural characteristics that make it attractive as a bearing material. Tin coatings applied by chemical immersion processes have been used for aluminum-alloy automotive pistons to safeguard the piston against scuffing during initial operation. The layer of tin permits closer initial fit with an added margin of safety. Brass coatings similarly applied have been used for parallel applications with good results. "Soft" oxide coatings impregnated with graphite-containing compositions have been evaluated for piston applications and also found suitable.

The most important commercial use of the film produced by the zinc immersion process is the preparatory treatment for electroplating, as mentioned pre-



Electroplating on aluminum is used for many applications, among them: pump bodies and cylinders, which are hard chrome plated for wear and erosion resistance; electronic devices, plated with copper and silver for conductivity and ease of soldering; cable terminals, plated with tin for the same reason; and a series of selenium rectifier plates, plated with nickel for conductivity and then coated with selenium.

viously. Another commercial application is the use of the zinc immersion process as a surface preparatory treatment for the application of enamel.

Nickel can also be deposited on the surface by a simple immersion process. The process has a high rate of deposition and may be the most practical method for applying nickel for certain commercial applications.

Paint, Enamel and Lacquer: Aluminum alloys are not difficult to paint, and if proper surface pretreatments are employed adhesion is as good as or better than with other metals. Methods for treating aluminum surfaces for painting are generally divided into three classes: (1) mechanical, (2) solvent, or (3) chemical or electrochemical.

Surface roughening by mechanical methods is ordinarily not required to secure good paint adhesion but is used for special conditions of service. For any surface preparatory procedures employed, preliminary treatment is necessary, of course, to remove all grease and dirt from the surface.

Solvent cleaning and its variation, including phosphoric acid mixtures, prove adequate for many applications, but for severe service conditions, other supplementary chemical or electrochemical treatments should be employed.

For severe service conditions, chemical or electrochemical treatments which result in the formation of an oxide coating provide the best surface preparation for painting. These include anodic oxide, chromic acid anodic, chemical-oxide, or proprietary processes which produce phosphate films on the surface. As with other metals, several different primers may be used on aluminum surfaces. Selection of the proper primer depends upon the service conditions.

On surfaces that are exposed to corrosive conditions, for instance, primers containing zinc, strontium or calcium chromate are used. Lead-pigmented primers should not be used on aluminum because of the danger of galvanic corrosion. With the recent introduction of so-called "wash coat primers," a new method of priming is available. This system is generally recommended for priming assembled parts when there is danger of acid entrapment in crevices. If any acid is retained in crevices, it will cause breakdown of the paint film.

After a satisfactory priming system has been applied, a finish system is applied to meet requirements of appearance and protection for the particular application. One precaution must be observed in the choice of finishing systems employing high temperature baking (over 300 F) on heat treatable alloys such as 17S or 24S. Heating to these temperatures causes metallurgical changes in the alloy that result in lowered mechanical properties and resistance to corrosion.

Ceramic coatings may be applied to aluminum alloys. Recent developments in low-melting-point vitreous enamels have resulted in coatings with superior impact and flex resistance and good resistance to thermal shock. Enameled aluminum can be cut and mildly formed after firing. Since vitreous enamels are fused at a fairly high temperature, care must be taken in the selection of alloy, gage and temper to minimize such effects as excessive distortion and softening of the base metal. These new ceramic coatings are resistant to mild acids and they are obtainable in a range of colors. Although present commercial applications are confined mostly to architectural types, recent developments indicate this finishing system may prove successful in protection of aluminum in applications involving exposure to elevated temperatures or unusual corrosion conditions.

SPECIFICATION OF

color in finishes

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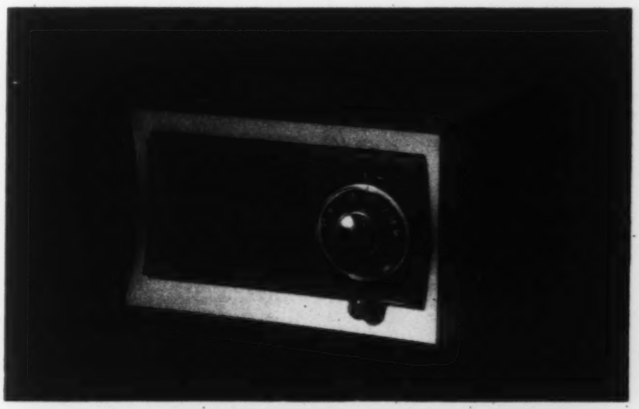
DESIGNERS of machines and many other manufactured articles must today, more than ever before, consider the factor of color. The growth of color consciousness in the mind of the purchaser in recent years has been phenomenal.

This fact may be attributed to the development of synthetic dyes, which has resulted in an overwhelming flood of eye-catching hues, tints, and shades in wearing apparel, materials for home decoration and other commodities. Color photography and a greater use of color printing have brightened our books, magazines and advertising media. Color has made motion pictures more realistic. Consumers, becoming more appreciative of color and more color-sensitive, want more of it in the machines and appliances they use both at home and at work.

Thus, a new and growing problem is presented for the machine designer. Not only must he make his products more efficient, but he must add an artistic touch with color as well as form. He must be judicious in his selection of colors and color combinations. He must know when and where to use color, as well as which colors to select. Perhaps the most important consideration he must make is the psychological influence of color on sales and production. Finally, he



Bright red, an eye-catching and appealing color, has distinct advantages in show windows and sales areas. In this Sylvania table model radio, the red-pigmented plastic case has been carefully designed with a gold finish and knobs to provide a lively combination that "stops" prospective buyers, and yet has a distinguished appearance for home interiors.

TABLE 1

ORGANIC AND SYNTHETIC FINISHES

FINISH	COLOR RANGE	SURFACE TEXTURE
Japans	Pigmented to provide deep, dense black. Dark browns may be produced.	Glossy to flat. Smooth surface.
Oil-base Coatings (oleoresins)	Clear varnish is amber-colored with depth dependent on type of resin. Pigmented grades possible, although not particularly suited to white or pastel shades.	Glossy to flat enamel-type surface depending on pigment vehicle ratio and pigment dispersion. Smooth-textured and wrinkle surfaces obtainable.
Phenolic Coatings (pure and modified)	Complete variety of colors.	Glossy to flat, with complete variety of surface textures.
Lacquers	Clear or pigmented coatings.	High gloss to dead flat. Extremely smooth surface may be obtained by proper solvent choice. Special finishes such as crackle, webbing and metallescent can be produced.
Alkyd Coatings	Wide range of colors.	Glossy to flat. Special effects of almost every kind can be attained, including metallic (hammered), wrinkle, metallescent and spatter.
Alkyd-Amine Coatings	Wide range of colors; particularly suitable for white and light colors.	Glossy to flat.
Styrenated Alkyds	Wide range of colors with excellent appearance.	High gloss to flat. Adaptable to metallic (hammered) finishes.
Silicones	Good range of colors including white.	Glossy to flat.
Vinyl Coatings	Clear, dyed or pigmented.	Glossy to flat.

must anticipate trends and know what colors will be in demand when his product reaches the market.

Basic Considerations: Before giving full play to his imagination in color styling the designer must take into account several vital considerations:

1. Environment in which the machine will be used.
2. How it will appear in show windows and sales rooms.
3. Usage or wear the machine will receive, and temperature to which it will be subjected.
4. Condition of the surface to be finished.

TYPICAL PROPERTIES	APPLICATION METHOD*	PRIMARY USES
Hard and durable when baked. Name is usually applied to black oil-base enamels consisting of pigment, a gum, drying oil and reducer, instead of only to the original black oriental lacquer.	Spray, dip or brush. Must be baked to obtain hardness, although can be air-dried. Requires rubbing between coats. Never applied over primer.	Inexpensive, hard finishes on: base plates for household appliances, interior stove parts and frames, sewing-machine heads, small machine parts. Largely replaced by synthetic baking finishes because of cost of between-coat rubbing.
Color retention only fair on exposure to high temperatures; clear varnish tends to yellow. Extremely hard if heat-cured. Heavy films possible because of high solids content. Suitable for indoor or outdoor exposure. Chemical resistance is fair; not resistant to strong organic solvents.	Spray, dip, roller or brush. Air-dried or baked, although baking is considerably slower than lacquers since hardening is a result of oxidation and polymerization instead of solvent evaporation. Must contain metallic driers for air drying. Should be baked for high hardness and best corrosion resistance. Oxide, phosphate, chromate or other pretreatment required for highest corrosion resistance.	Good corrosion resistance when heavily pigmented with red lead, zinc chromate or metallic powders. Largest application is for structural steel parts and relatively inexpensive products because of low cost. Now superseded by more versatile synthetic finishes for many machine applications.
Excellent durability, chemical resistance and moisture resistance. Modified phenolics have good abrasion resistance.	Spray, dip or brush. Relatively fast drying. Fast production obtained at high baking temperatures in neighborhood of 300 to 350 F.	Automotive primers and surfacers, marine finishes, electrical insulation, food and chemical processing equipment.
For indoor and, when so formulated, for outdoor conditions. Excellent toughness and flexibility. Nitrocellulose lacquer is inflammable, but other "lacquers" formulated with thermoplastic resins modified with alkyds or other oxidizing resins have low flammability and good heat resistance. Nitrocellulose type has best water resistance and adhesion to metals.	Spray is most usual, but can be dipped, roller-coated or brushed. Lacquers are very fast-drying; may be air-dried or force-dried at temperatures under 180 F. Individual coats are thinner than varnish or synthetic-finish coats. Solvent cleaning of the metal is usually necessary, with a chromate or phosphate pretreatment for best moisture and corrosion resistance. Pretreatment necessary for application to aluminum or magnesium.	Pigmented metallic lacquers are used as automotive finishes, and on aircraft because of light weight, although transparent nitrocellulose lacquers are most widely used. Small parts may be finished in one coat with metallic-powder filled lacquers.
Better gloss retention at high temperatures than phenolic or oil base coatings. Good durability, hardness, heat resistance, grease and oil resistance with good adhesion and flexibility. Fair alkali and water resistance.	Spray, dip, roller or brush. Metallic driers must be incorporated for air drying which can be very rapid with certain formulations. Special textural effects require baking, but may be applied over smooth, bare metal. Usual surface treatment involves degreasing, rust removal, chromate-type primer and air-dry or bake.	Variety of indoor and outdoor products, including refrigerators and kitchen appliances. Widely used as automotive finish.
Excellent gloss retention and color stability at elevated temperatures and after prolonged exposure to light. Good hardness, chemical and abrasion resistance. Excellent oil and grease resistance. Melamine formulations are resistant to arcing and are especially stable.	Usually sprayed or dipped. Baking is necessary. Similar metal treatment to that for alkyds.	Refrigerators, stove parts and other kitchen appliances, automobiles, hospital equipment.
Good stability and color retention. Restricted compatibility with other synthetic-resin formulations.	Spray, dip, roller-coat or brush. Air-drying and baking types. Some air drying types dry tack-free in 15 minutes—about as fast as lacquers. Baking enamels can also be made fast-drying. Metal treatment as for alkyds.	For smooth metallic parts where appearance is the main factor.
Outstanding temperature stability and resistance to heat. Pigmented formulations have high gloss with pure colors and tints. Good hardness, weathering resistance and wet-insulation properties. Formulations containing aluminum provide exceptional heat resistance.	Spray or dip. Must be baked from 15 to 30 minutes at 350 to 425 F.	Gas heaters, stoves, heating equipment, refrigerators, electrical equipment.
Flexible, tough, and resistant to oils, foodstuffs and many chemicals. Adhesion is only fair but is improved by incorporating other resins. Thick films for both protective and decorative purposes are provided by vinyl dispersion coatings (organosols).	Spray, dip or brush. Can be air-dried but is often force-dried for better adhesion. Metal must be precleaned and degreased in all cases.	Formulations containing chromates are used as wash primers on aluminum, galvanized iron and steel for application of alkyd-base finishes. Refrigerators and washing machines are finished with chemical-resistant formulations.

* Normal precleaning to free surface from grease and dirt is presumed. Chemical pretreatment or undercoats are often necessary.

In many cases, only a small number of finishes will meet the specifications, and these may be available only in limited colors. TABLE 1 outlines the major properties of commercially available finishes.

Environment: One of the most important considerations in choosing a color is the effect it will have on the environment in which it is to be used. For this reason, office equipment such as typewriters, calculators and billing machines have been the subject of careful study. The first improvement made on the appearance of typewriters was replacement of the old glossy black surface with a black wrinkle finish which eliminated glare and eye fatigue.

Black, however, shows dust and eraser particles and was soon replaced by gray. Radical departures to vivid colors were not considered because they would not produce the impression of efficiency an office must convey. The dignified environment of an office was the criterion, and the natural grays selected proved successful. These colors lightened the working areas where they were used and did not show dust as readily as black.

Various shades of gray have been developed, some manufacturers trying to distinguish their brands through the use of individual tones of gray. Some of these have a yellow or green cast, and others a warm rose cast. Blue grays, less neutral than the other shades, have not proved as popular. One large manufacturer even experimented with shades of tan and beige. The finishes were satisfactory but did not meet with as much popularity as gray tones.

The grays have since been sharpened by the addition of chromium trim and color accents, and now bright colors—among these red—are used on keys and key panels for accent, brand identification and popular appeal.

Manufacturers of small machines and machine tools for hobby shops and home work shops also strive for popular appeal and must utilize gay colors to achieve it. Often displayed in show windows and on sales floors, this equipment must stand out among competitive items. At the same time, environment cannot be ignored. Consequently, blues or blue grays are most frequently favored, reflecting the serious production aspects of the equipment. Red or yellow trim is usually added, however, in keeping with the brighter decorating schemes of the work shop areas which are often a part of or adjacent to recreation rooms, and for better appearance on sales floors.

Electric fans are also an example of modernization with new colors. Because of their suggestion of coolness, soft greens, blue-greens and gray metallic finishes have proved to be popular colors for fans, replacing black formerly used. These metallic finishes are also being applied on new vacuum cleaners.

Sales Appeal: Manufacturers and designers in many fields are also stressing color as an implement to sales promotion. Modern streamlining of lawn mowers, for example, has made the customary red and green finishes of a decade ago as outdated as the black Model T. More expensive lawnmowers today have aluminum handles with the remaining finish in harmonizing tones of creams, ivories, and yellows—with green, yellow, orange or red accents. The lighter colors not only make the mower more striking in show windows and sales rooms, but also more visible in grass.

Color is also added solely for its sales promotion value on many farm machinery items. Harrow disks and plows, for example, may be finished in brilliant transparent blues and reds. With constant use, these finishes eventually wear off the working surfaces. Meanwhile, however, they have served as protection against rust and have created additional sales appeal.

Addition of color only for its sales promotion value may not always prove to be wise. White has long been preferred for household kitchen and laundry appliances such as refrigerators, washers, ironers and ranges because it denotes cleanliness and may be in-

The finish on an outboard motor is called upon to resist wet conditions and quite a bit of wear. At the same time, sales appeal is necessary. Chris-Craft has found one combination in this medium blue—strong-colored enough to stand out on sales floors, yet dark enough that chance nicks or scratches do not show excessively.

Large areas of yellow on this John Deere tractor, left, have sales promotion value when the tractor is displayed along with other farm machinery. At the same time, use of a medium yet colorful green harmonizes well with the yellow, providing a color combination without the violent contrast that might not appeal to all purchasers.

Colors for many home appliances, right, such as vacuum cleaners, must be neutral enough to blend with any decoration scheme. In this Hoover cleaner, judicious use of a blue and beige color combination results in a color combination that can be used in almost any environment. A touch of red on the start button provides a bit of colorful trim.

A neutral finish can sometimes be an advantage, left, lending a "professional" appearance that more colorful finishes would lack. The warm gray wrinkle finish on this Bell & Howell 8-millimeter camera has a second advantage in that the finish will not be marred by handling.

corporated into all color schemes. Some manufacturers have experimented with primary colors on stoves and refrigerators—reds, blues and greens. Placed in show windows and sales rooms, the colored appliances attracted attention but did not sell at any appreciable rate. In another case, a clothes washer was introduced in a clear blue color. One housewife, however, offered an objection on the grounds that the blue washer was too strong a reminder of "blue monday."

Since appliances represent an expensive long-term investment, most housewives seem to have a strong preference for white, which blends with any color and decorating theme. A bright-colored appliance limits the variety of colors which could be used on kitchen walls, ceilings, woodwork and floors — and there are few housewives who will endure one color scheme for the life of her refrigerator or range.

In a further attempt to utilize color for sales appeal, some manufacturers have retained the white exteriors of their refrigerators but have added color on the interior. One manufacturer produces refrigerator shelf hardware in attractive colors, and another has adopted a whole new color scheme for the entire refrigerator interior.

The housewife's objection to colored refrigerators, ranges and washers does not extend to small home appliances, however. Bright reds, blues, greens and yellow are suitable for fruit juicers, mixers, grinders and other small equipment. Because of their relatively small size, these appliances add an interesting color accent which supplements the general color theme of the kitchen area. At the same time, finished in attractive colors, they have more sales appeal in show windows and on store counters than when finished in white.

Color is being utilized today even for trim and name plates to supplement product design and win buyer attention. Trim also serves the purpose of dividing two segments ostensibly of the same color, hiding the fact that these segments may be of slightly different shades.

Usage or Wear: End-use of the machine often determines or limits the color, since external service conditions may necessitate the use of a finish with particular characteristics, or may suggest a finish that will show the least effect of usage.

A machine designed for heavy duty industrial service—a lathe, milling machine, planer or shaper, woodworking machine, paper mill or printing press—is usually finished in standard gray. Subject to considerable abrasion and hard handling, oil, grease, ink and other disfiguring materials, the machine is usually sold on specifications and data, and is seldom displayed in showrooms. As a result, attention-getting colors designed for popular sales appeal are not necessary.

White with chromium and stainless steel trim, for example, predominates for home laundry equipment because of proven resistance to alkali. Blues and greens tend to show alkali marks readily.

In the finishing of space heaters for room use, the temperature at which the heater is operated is an important consideration because high heat eliminates the possibility of using many light colors. The greater the heat to which the finish is subjected, the deeper the color required to minimize discoloration.

Now, however, color possibilities are being widened through the use of silicone finishes which withstand higher temperatures than customary organic finishes, and some relatively light finishes can now be applied successfully.

Selection of colors for central heating plants in the home can be made with greater freedom because of the jacketing which keeps the exterior furnace surfaces at a relatively low temperature. For this reason, furnaces which are to be situated in homecraft areas and recreation rooms may be finished in gay colors. Hammerloid and Metallescent and other metallic finishes in blue-greens, greens, reds and off-shades of gray give the furnace jacket a colored metallic appearance which has proved popular. Buff shades have been used frequently to create a rich, warm appearance.

Surface Condition: Condition of the surface may not always be an important consideration, since often the surface is prepared for subsequent finishing operations. Finishes can be selected, however, which minimize surface defects when extensive surface preparation is not deemed necessary or desirable.

Condition of the surface, for example, is one of the most important considerations in the selection of colors for home heating furnaces. Some furnaces have rough metal edges, weld marks and rivet heads which have to be ground down. A hammered metal finish helps make these irregularities less conspicuous, especially in lighter shades, due to the higher aluminum content of the lighter colors.

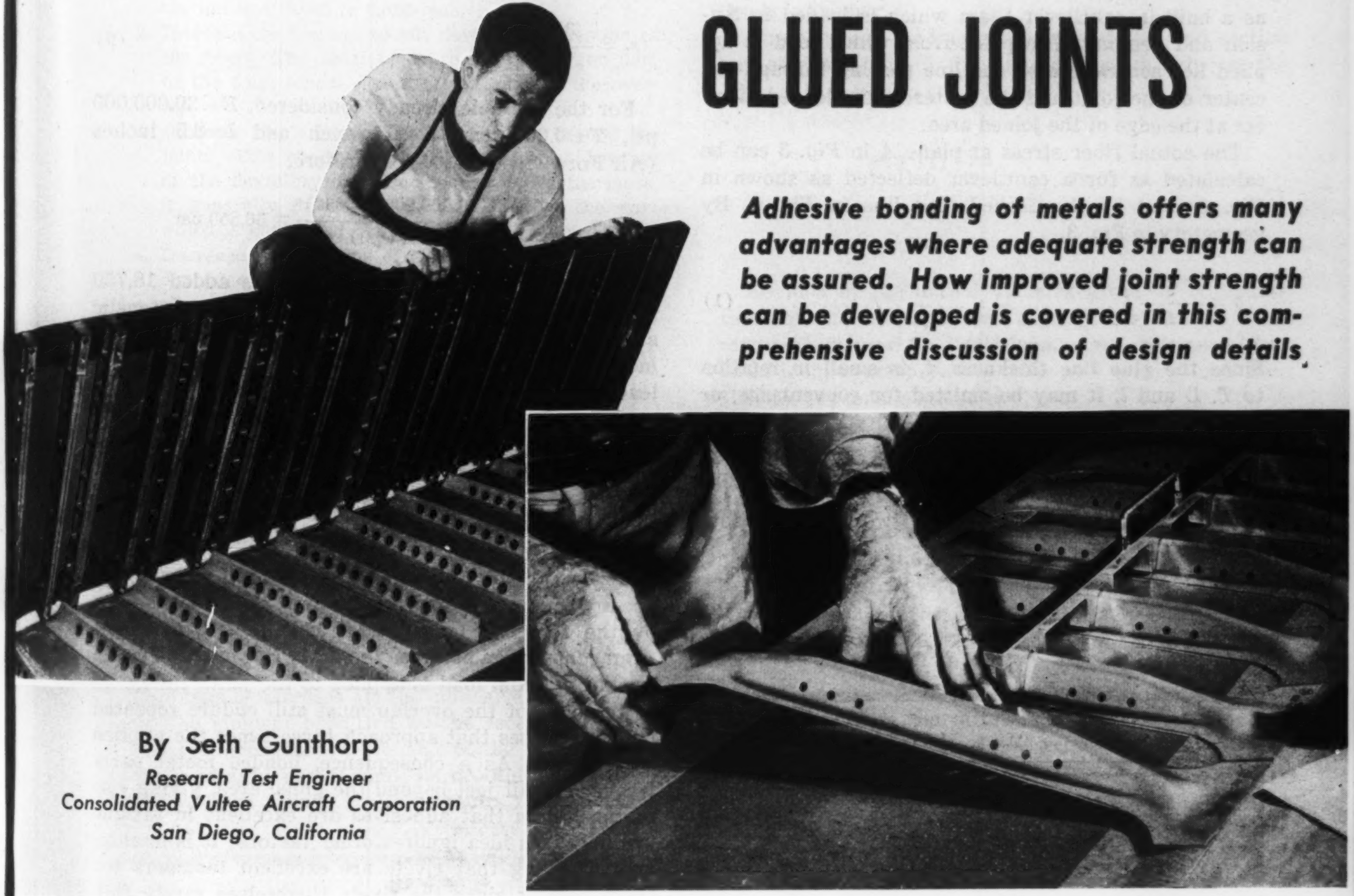
Summary: Today, with all kinds of articles appearing in colors from one end of the spectrum to the other, the extent to which the public's desire for color has developed can be judged by using a famous quotation from Henry Ford. When he was asked early in the century what color he wanted for his historic Model T, he replied, "Any color, just so it's black."

We've come a long way since then. And designers who wish to utilize the advantages of color must keep the basic factors governing color selection well in mind. They might be summarized as: (1) choosing a color that is acceptable in the normal environment of the machine; (2) making the machine striking and appealing in sales areas by use of color; (3) considering the effect of service conditions, such as wear, disfiguring conditions or heat, on the color; and (4) weighing the importance of covering surface defects or blemishes with a finish.

Relative importance of each of these factors differs with each product. It is up to the designer to consider each carefully and choose the finish that meets all the fundamental criteria successfully.

design of GLUED JOINTS

Adhesive bonding of metals offers many advantages where adequate strength can be assured. How improved joint strength can be developed is covered in this comprehensive discussion of design details.



By Seth Gunthorp
Research Test Engineer
Consolidated Vultee Aircraft Corporation
San Diego, California

Fig. 1—Above—Full-depth stiffeners for the B-36 trailing edge panel, left, and redesigned panel, right, with tapered stiffeners which increased panel stiffness as well as reduced stress concentrations at the ends

STRUCTURAL adequacy of glued joints is continuing to be proved by their widespread and growing use in the aircraft industry. Concurrently, design principles, analysis methods, test criteria, etc., have been developed for the engineering of metal-adhesive joints.

Good joint design requires understanding and regulation of factors that influence the strength of both the metal member and the adhesive bond itself, *Fig.* 1. Two basic concepts dominate glued-joint design: (1) All failures are tensile failures, and (2) leveling of tensile stresses is the only path to better design.

Stresses in the Metal: By common practice the strength of a structural adhesive is judged according to the load it supports in shear when tested between the overlapping portions of two members loaded in tension. A shear strength value in psi is obtained simply from division of the tensile load by the adhesive area. Although not definitive of the detailed stress picture, this method of strength determination has the virtues of being simple and easily standardized.

Armed Forces specifications for structural adhesives require that tests be made in simple ½-inch overlap joints of 0.064-inch clad 24ST-3 aluminum alloy 1 inch wide, *Fig. 2a*. When such a joint is loaded in shear by application of tensile forces at the ends, say to 1000 lb, the specimen takes the shape shown in *Fig. 2b,* and at a somewhat higher load, that shown in *Fig. 2c.*

Above a tensile load of 1200 lb, the shape shown in *Fig. 2c* becomes permanent—proof that the yield point of the metal has been exceeded. However, the axial stress is less than 20,000 psi (1200/0.064) whereas the yield strength of the material is about 50,000 psi. The question is: How did the additional 30,000 psi enter the problem?

The answer is supplied by analysis of the simple overlap joint which is common to the great majority of thin sheet joints. *Fig.* 3 shows part of the joint as a built-in cantilever beam which is loaded in tension and bending. The point from which load is applied lies somewhere on the line passing through the center of the joint and the center of the loaded member at the edge of the joined area.

The actual fiber stress at plane *A* in *Fig.* 3 can be calculated as for a cantilever deflected as shown in *Fig. 2c* and by the dashed load line in *Fig.* 3. By geometery in *Fig.* 3,

$$\delta = \frac{T+t}{L}\,l \quad \text{(1)}$$

Since the glue line thickness, *t*, is small in relation to *T*, *L* and *l*, it may be omitted for convenience, or

$$\delta = \frac{Tl}{L} \quad \text{(2)}$$

For a cantilever the following two basic relationships hold:

$$\delta = \frac{wl^3}{3EI} = \frac{Ml^2}{3EI} \quad \text{(3)}$$

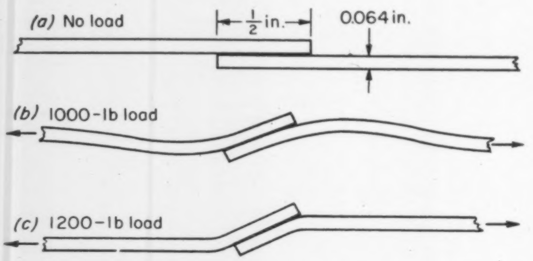


Fig. 2—Glued joint test specimen under three stages of tensile loading

$$s_t = \frac{My}{I} = \frac{MT}{2I} \quad \text{(4)}$$

where E = modulus of elasticity of the sheet, I = beam section moment of inertia, m = bending moment, $y = T/2$ and the other symbols are identified in *Fig.* 3. Combining Equations 2, 3, and 4 yields

$$s_t = \frac{3ET^2}{2lL} \quad \text{(5)}$$

For the example already considered, $E = 30{,}000{,}000$ psi, $T = 0.064$-inch, $L = 0.5$ inch and $l = 3.5$ inches (Air Force Spec. 14164). Therefore,

$$s_t = \frac{3(30{,}000{,}000)(0.064)^3}{2(3.5)(0.5)} = 36{,}850 \text{ psi}$$

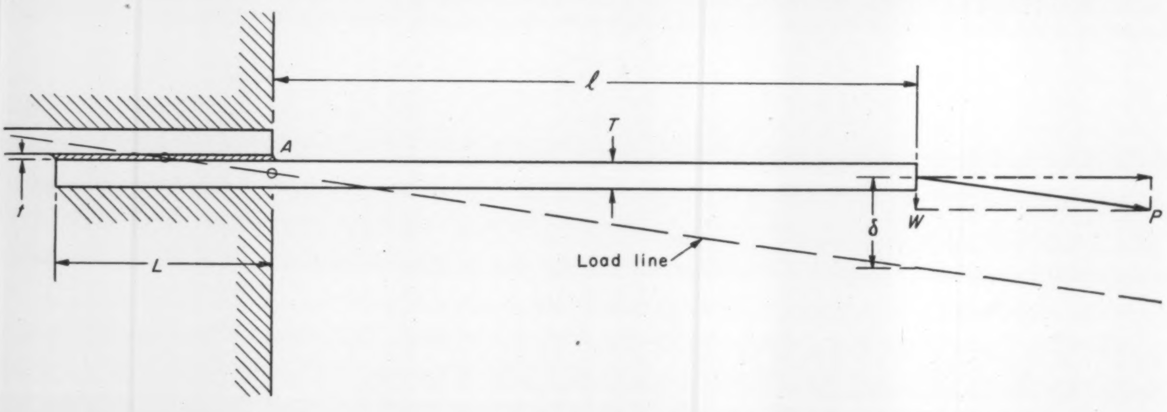
To this fiber stress due to bending is added 18,750 psi due to direct axial loading, or the total tensile stress at *A* is 36,850 + 18,750 = 55,600 psi. Only a little more than one-third of the total is due to the axial load, almost two-thirds to the bending load.

Under static loading, the metal yields at a tensile load of about 1250 lb (2500 psi shear stress over the ½ sq in. bonded area). At that point the adhesive must hold together two strips of metal with one of them undergoing permanent set at the edge of the glue-metal interface.

At lower loads the proportion of total fiber stress due to bending is somewhat lower than that shown by the foregoing calculation. This fact is apparent from comparison of *Figs. 2b* and *c*. However, when an oscillating axial load is applied to the joint, the metal at the ends of the overlap must still endure repeated tensile stresses that approach three times the applied axial stress. As a consequence, bonded metal parts frequently fail just beyond the glued area, giving rise to the notion that adhesives are excellent in fatigue loading. This idea ignores other factors; it is analogous to saying that rivets are excellent fasteners for fatigue loads since the rivets themselves rarely fail.

Examination of Equation 5 shows that maximum stress due to bending can be reduced, and thereby

Fig. 3—Diagram for analysis of a glued overlap joint treated as a built-in cantilever



the efficiency of the metal members raised, by the following changes:

1. Reduce the thickness of the metal at the edge of the joint to minimize the eccentricity of loading. Also, the thickness of the glue line, which was neglected in the foregoing analysis, raises the eccentricity of the loads and should be kept within the limits of 0.005 to 0.010-inch.
2. Increase the overlap to cut down the deflection of the beam. The axial load produces a larger part of the total tensile stress at the ends of the overlap.
3. Increase the length of the joined parts beyond the joint. This change is usually ineffective because of the flexibility of these members. Furthermore, it generally involves the dimensions of the part which is controlled by other design requirements.
4. Decrease the modulus of elasticity. This property, dependent upon the material, usually cannot be altered because other factors generally govern the choice of material. Also, if the yield stress is lowered as the modulus is reduced, little gain in joint performance will result.

Stresses in the Adhesive: Evaluation of stresses in the adhesive layer is not as simple as determination of stresses in the metal members. Loads applied to the metal parts and the deformations which result from these loads apply nonuniform shear and tensile loads to the bond. These stresses are, to a great degree, a function of the properties of the adhesive and its thickness, and the geometry of the joint itself. Characteristic distribution of shear stress over the length of the overlap is shown in *Fig*. 4.

The tensile stresses in the adhesive layer arising from the moment produced by the eccentricity result in maximum stresses at the edge of the joint. A simple yet exceedingly useful analysis of this aspect of the adhesive layer tensile stresses results from a method suggested by O. F. Oldendorph. In this method the area of the bond is considered to be a section of a solid bar in bending and the stresses are those due to the M_y/I forces which exist as a result of bending loads in the bar.

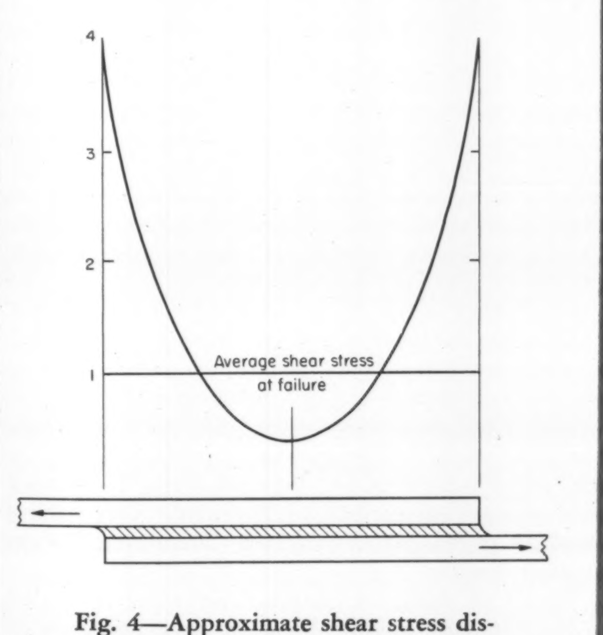


Fig. 4—Approximate shear stress distribution in a simple overlap joint

The assumed loading conditions of the load section are shown in *Fig*. 5. Tensile stress of the glue at the edge of the overlap is

$$s_{tg} = \frac{My}{I} = \frac{P(T+t)\dfrac{L}{2}}{\dfrac{L^3}{12}} = 6P\,\frac{T+t}{L^2} \quad \ldots\ldots\ldots\ldots (6)$$

An idea of the actual value is given by computation for the test specimen already considered. With metal thickness $T = 0.064$-inch, glue thickness $t = 0.006$-inch, overlap $L = \frac{1}{2}$-inch, and tensile load $P = 1000$ lb, the tensile stress is

$$s_{tg} = 6(1000)\frac{0.064+0.006}{0.5^2} = 1680 \text{ psi}$$

Factor $(T+t)/L^2$ in Equation 6 is significant because it relates the tensile stress in the adhesive due to bending and the applied axial load. Called the peel factor, $(T+t)/L^2$ should for design purposes be maintained in the region of 0.05 and should never exceed 0.1.

Another source of tensile stress in the adhesive joint arises from the different elongations occurring in the metal members at the regions of high stress at both ends of the overlap. Greater elongation of the one member tends to bend the members in a direction opposite that resulting from the bending moment in the joint due to eccentricity. Consequently another tensile component is added to the loads endured by the adhesive at the edge of the overlap.

These factors depend upon the properties of the adhesive and of the overlapping materials. Since the properties of the adhesive in shear and in tension are known to be dependent upon the state of elongation

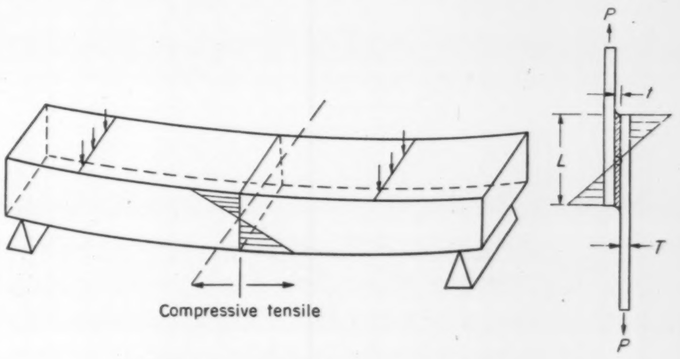


Fig. 5 — Diagram for analysis of tensile stress in bond layer according to Oldendorph's method

or stress, they are not subject to rigorous analysis. However, inspection of the relative magnitudes and distributions of stress, leads to changes that can be made to reduce the height of stress peaks that otherwise prevail.

Design Recommendations: Obviously, a tapered scarfed joint with a high length-to-thickness ratio is the ideal solution. There is no eccentricity. Tensile stress in the adhesive is minor and is reasonably uniform over the length of the scarf.

However, it is unfortunate but true that the scarf joint is difficult and expensive in sheet metal. One might say it is impossible as a matter of cost, factory methods, and manufacturing convenience. Consideration of the scarf joint, however, leads to several ideas which can be applied and which reduce both the tensile and shear stresses in the adhesive as well as in the metal parts.

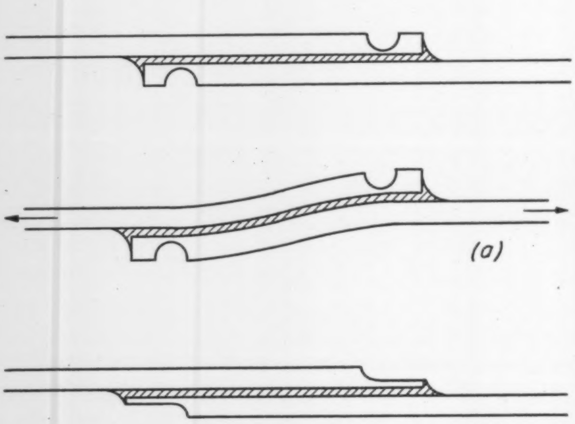


Fig. 6—Designs for minimizing tensile stress at edge of overlap. Joint *c* is not recommended for fatigue loading because of increased loading eccentricity

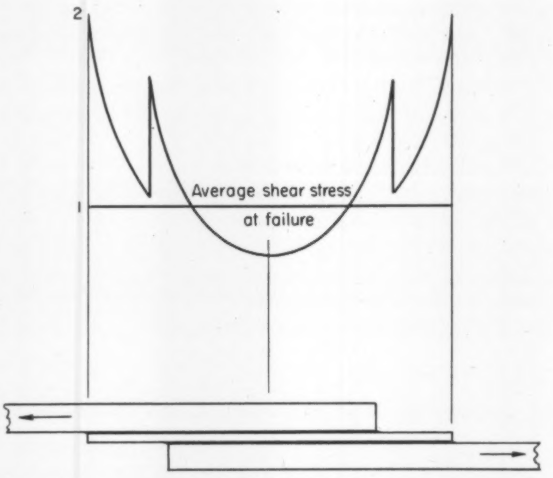


Fig. 7—Typical shear stress distribution in a stepped overlap joint

Any device lowering the stiffness of the member which is under low stress is beneficial to the adhesive. It allows that member to follow the highly-stressed member to which it is bonded, and thereby reduces the tensile stress at the edge of the joint. One way is to increase the overlap since this, in effect, slenderizes the beam. A better way is to reduce the thickness of this piece of metal if it can be done, ***Figs.*** **6*a*** and ***b***. However, these designs are usually expensive. The same result can be achieved through increase of the thickness of the joint by a stepwise procedure—interposing one or more thin flexible members between the two stiff members, ***Fig.*** **6*c***. Thus, each one increases the stiffness of the loaded member by a small increment as the center of the joint is approached, ***Fig.*** **7**. Preferably these elements of the joint should be a material which has a low modulus, or at a high elongation, so that the adhesive will be able to carry them with the more highly loaded member wherever the forces applied require it to go.

The design shown at 6*c* is excellent for static loads but not suitable for fatigue loads due to the increase in eccentricity. For fatigue loads the somewhat less simple design in ***Fig.*** **6*d*** gives excellent results.

Very high shear stresses are present in the neighborhood of the edge of the overlap. Since these stresses are greater for long overlaps, the strength of a glued joint connot be increased to the ultimate strength of the metal merely by increasing the overlapping length.

The sharp break in material continuity at the edge of the joint produces severe stress concentrations even if there is no eccentricity. This situation is frequently aggravated by use of metal as it comes from the shear. The wire edge acts as a knife, frequently cutting

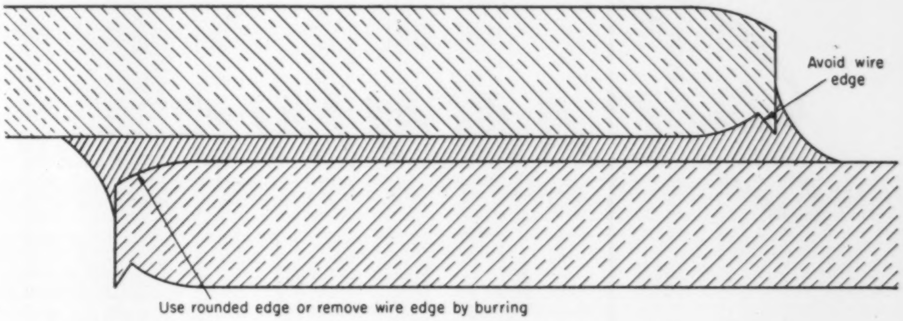


Fig. 8 — Detail at end of metal elements showing how a starved joint, and reduced strength, can be avoided

completely through the adhesive layer, *Fig.* 8.

It is the consensus that thin glue lines are stronger than thick glue lines. With a thin layer of the adhesive, no part of it is very far away from the reinforcing influence of the metallic substrate. This effect is chemical as well as physical in nature. On the other hand, if the thickness of the adhesive layer becomes too small (due to excessive pressure or flow during cure) the danger of starved joints becomes more severe. The thinnest layer then must endure the greatest shear stress, and rupture may begin at low average stresses. Ideal design would have the adhesive layer increasing in thickness from the center to the edges of the joint. Then shear deformations per unit thickness and shear stresses would be uniform.

Most structural failures, whether on overlap test specimens or sandwich panels, shovel handles or wing spars, result from stress concentration. Stress concentrations in adhesive bonded structures arise most frequently from notches, or sharp changes in section. Stress concentrations also exist in starved joints.

The best example of a starved joint is given by the sandwich panel where the skin is in direct contact with the honeycomb core. In this situation a low pressure over the entire panel applies tremendous pressure to the adhesive on the edges of the core and complete "squeeze out" occurs during the early stages of the cure. In effect, there is no adhesive material between the core element and the facing. When such a panel is loaded, any deformation whatever will result in infinite elongation—failure—at the extreme root of the fillet between core element and facing.

If during manufacture, the core is held a few thousandths of an inch away from the facing by means of an adhesive coated scrim cloth or by flock applied to the core with wet adhesive, the starved joint effect is eliminated. Between the two loaded members is a layer of adhesive which can withstand moderate deflections without failure and in doing so permits the entire fillet to carry the load.

Application of this idea to sandwich panels does not result in a great improvement in the static ultimate strength in bending. However, the fatigue life of such a panel is approximately 10 times that of a panel without the scrim cloth spacer. Furthermore, these spaced panels will withstand handling and small accidents to which all production parts are subjected in factory operations.

Pivoted-Shoe Bearings for Piston Pumps

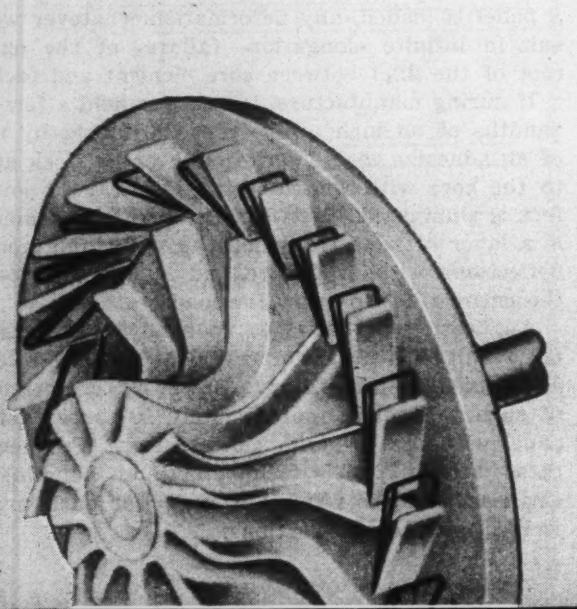
ROLLING contact bearings are ordinarily used to carry radial and thrust loads from rotating parts to stationary members in positive displacement hydraulic pumps and piston-type hydraulic motors. However, pivoted-shoe thrust and radial bearings might be used to advantage, because of their durability, in piston pumps which usually start at low loads and run at essentially constant speed.

To explore this possibility a wobble-plate type, variable-displacement machine was modified during Navy research. The rolling contact bearings which back-up the socket ring were removed and with only slight modification of the tilt plate, sets of radial and thrust shoes were substituted. The modified machine was subjected to a harmonic load cycle in which pressure in the lines was varied sinusoidally between zero and 2/3 of the maximum allowable pressure. The period of this pressure cycle was two seconds. After continuous cycling for 381 hours, the pivoted-shoe bearings were found to be in excellent condition.

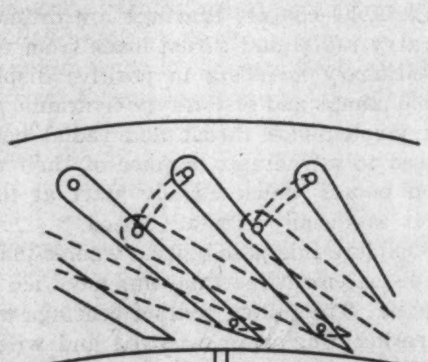
Correction

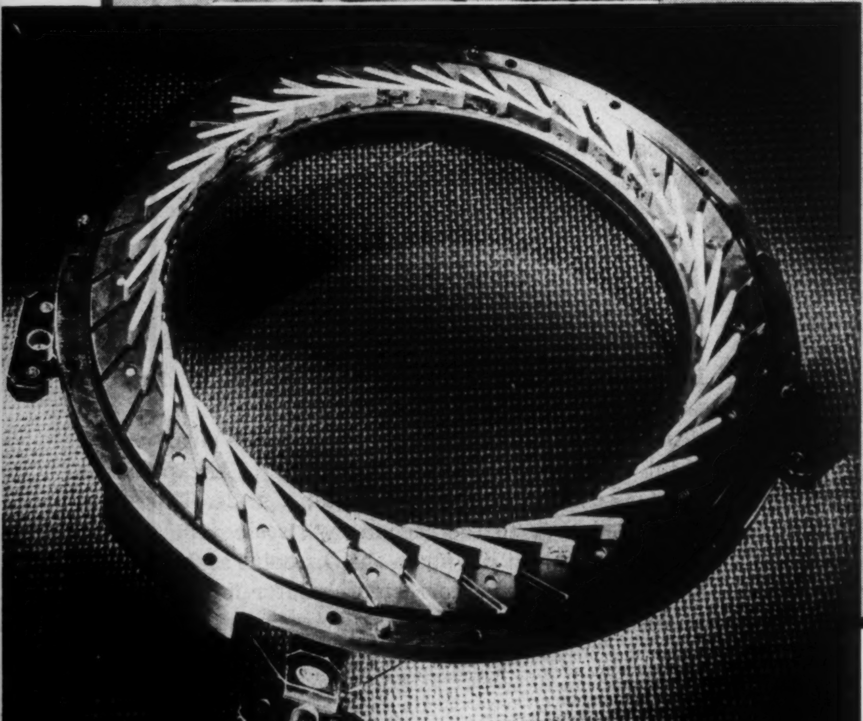
In the article, "Nomographic Method for Sleeve Bearing Analysis," August, Page 143, the secondary ξ scale in *Fig.* 6*c* should be numbered from 0.2 to 1. Additionally, use of the ξ scale is not shown clearly. The point on the Q_{c0} scale is connected to the point on the $l_{\mu 2}$ scale to intersect the main ξ scale. This point is carried over to the secondary ξ scale (the shorter one). A straight line from the Q_{c0} point scale through this value gives the corrected chamfer flow on the Q_c scale.

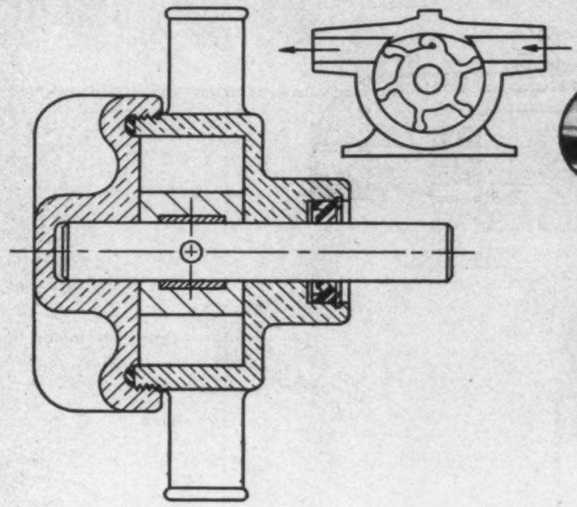
SCANNING the field for IDEAS

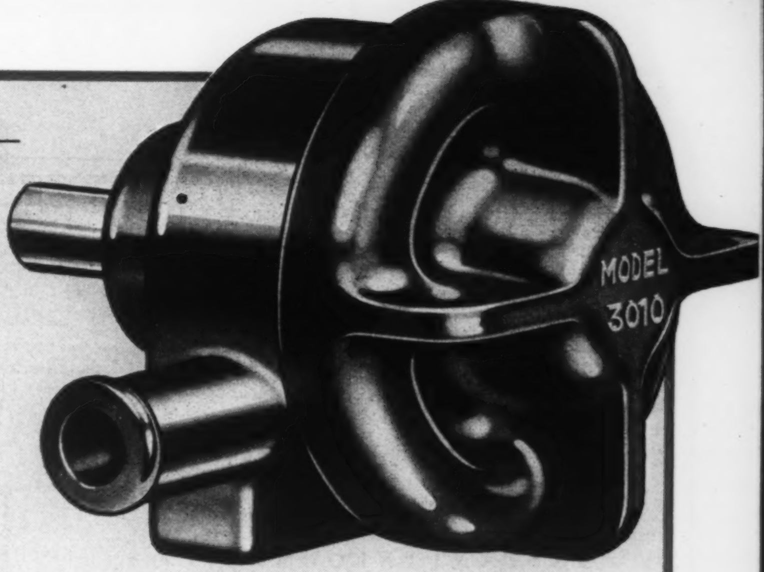


VARIABLE-AREA NOZZLES simplify matching power requirements and increase efficiency in air turbine drives. Developed by AiResearch Mfg. Co., movable vanes mounted on two concentric sliding rings provide variable-area openings to control the flow of air into the turbine wheel. Vane position is regulated automatically by a servomotor and governor system to adjust output torque and speed to meet power requirements, substantially reducing air consumption as compared to conventional throttling controls. Variations in inlet air conditions, which could have a pronounced effect on turbine performance, are compensated automatically by the design. Application of the variable-nozzle principle appears to be more suited to 90-degree radial turbines than other types which employ complex curve shapes because of the simple blade geometry and insensitivity to nozzle blade angle.

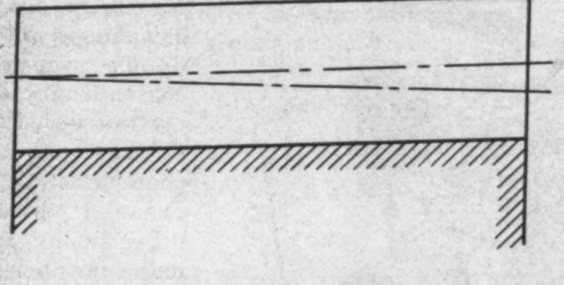


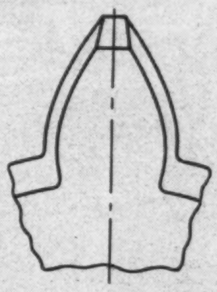




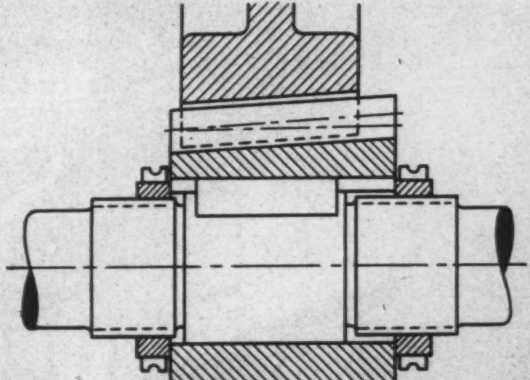


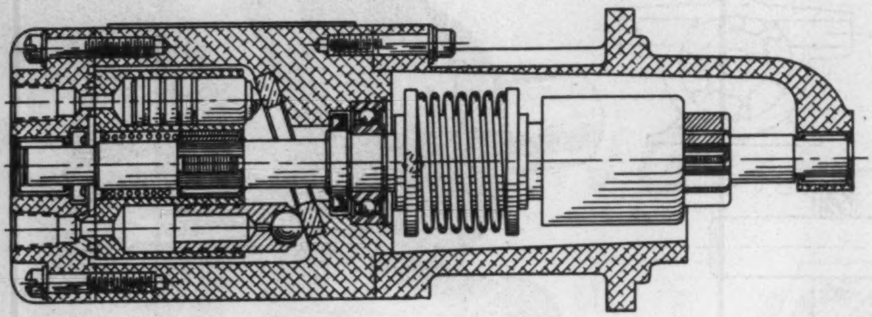
ALL-PLASTIC DESIGN of a rotary hydraulic pump body meets performance requirements to cost advantage and eliminates the need for conventional bearings. In the design developed by Jabsco Pump Co., a two-piece molded Bakelite body and a Neoprene impeller are employed to provide a rated output of 3.41 gpm at 1000 rpm. Construction of the pump, which employs two standard seals, an O-ring at the body junction and a shaft seal, simplifies maintenance and assembly; the low-friction plastic surfaces are self lubricating and wear resistant. Pumping action is provided by an offset wall in the rotor chamber which squeezes the flexible vanes to create the output cycle to deliver a uniform, continuous flow and also create a self priming effect when starting.

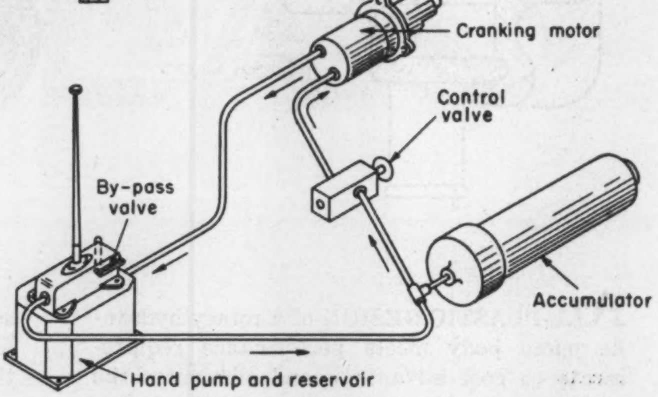




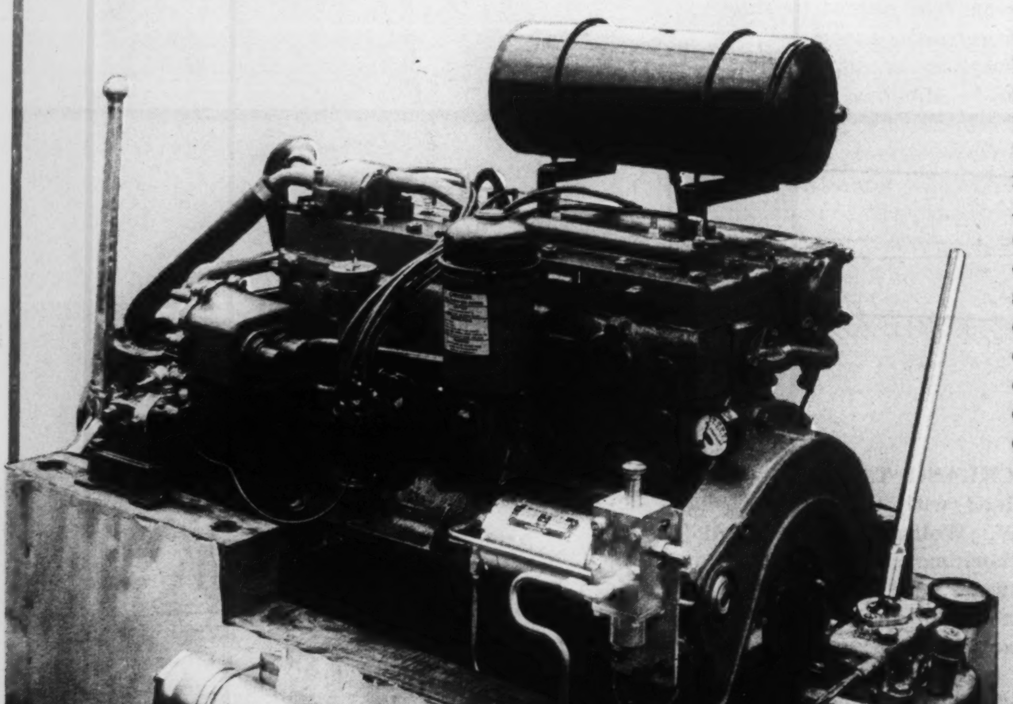
ADJUSTABLE BACKLASH TAKEUP for spur and helical gears is obtained with tapered teeth in a design described by W. Wolfstieg in *Zeitschrift Des Vereines Deutscher Ingenieure,* a German engineering publication. Play between meshing gear teeth is eliminated by displacement of the gears axially, facilitating assembly and compensating for production inaccuracies. Teeth are cut on a cone instead of a cylinder and with standard tools. Application of the system utilizes the principle of involute geometry that altered working pitch diameters produce conjugate action but at altered pressure angles. Tapers of 2 to 6 degrees are considered sufficient to eliminate play caused by machining tolerances and wear.



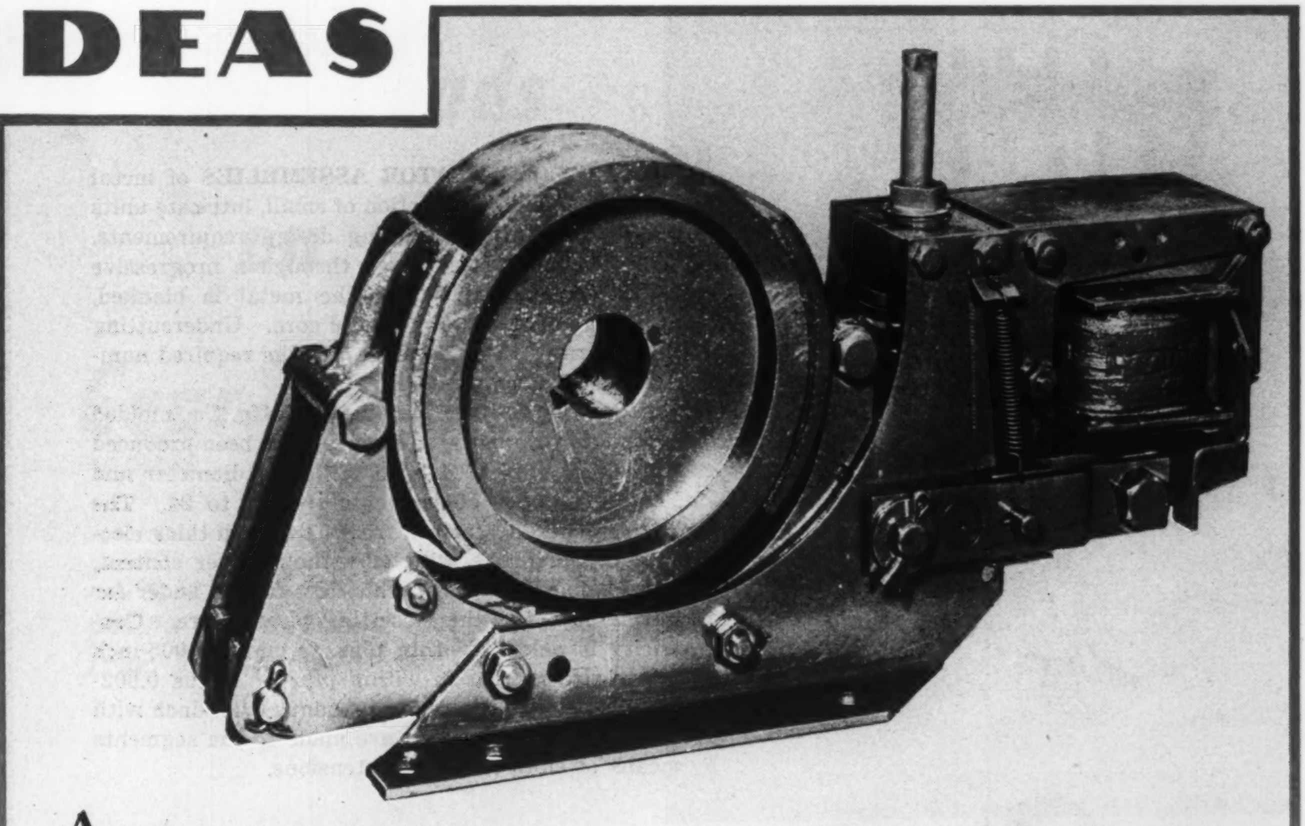




INSTANTANEOUS STARTING TORQUE for heavy-duty internal combustion engines can be obtained hydraulically with a cranking unit developed by Hydramotive Inc. Cranking force is produced by a wobble-plate type fluid motor operating in a closed circuit which contains a hydropneumatic accumulator for energy storage. Dependent on fluid motor size, starting torques up to 215 lb-ft can be developed at cranking speeds adjustable from 0-7500 rpm. System pressures of 1000 to 3000 psi are employed, and commercial oils, selected on the basis of climatic conditions, permit dependable operation at temperatures varying from −65 to 150 F. For installations requiring frequent starting, an engine driven pump and unloading valve may be incorporated in the system to supplement the standard hand pump and provide automatic recharging of the accumulator during engine operation. Advantages of the hydraulic system over conventional cranking systems include higher torque-weight characteristics, increased operational dependability and reduced maintenance.

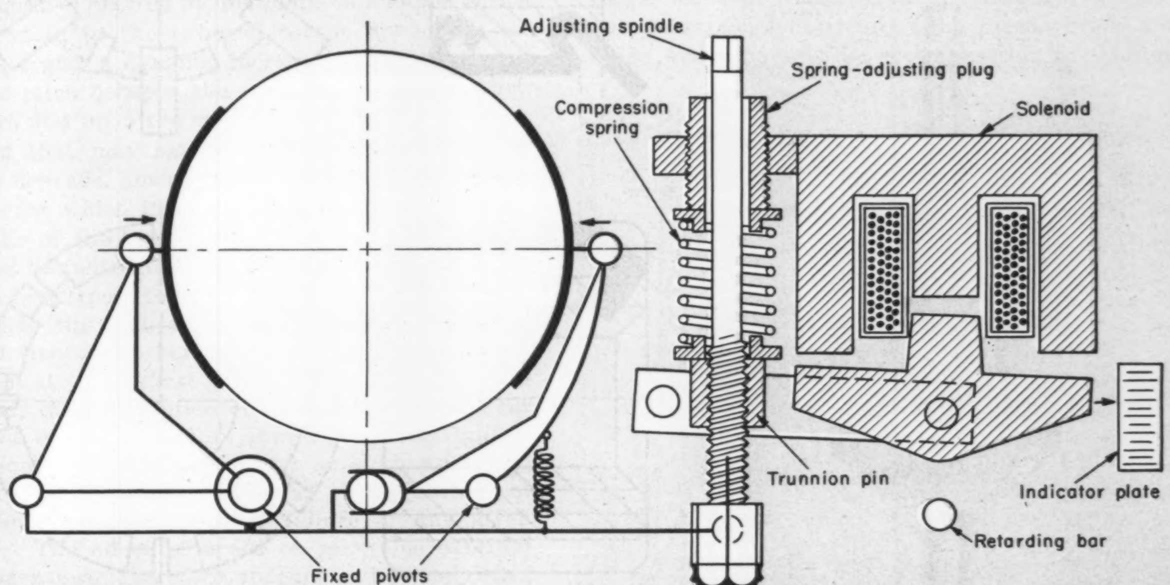


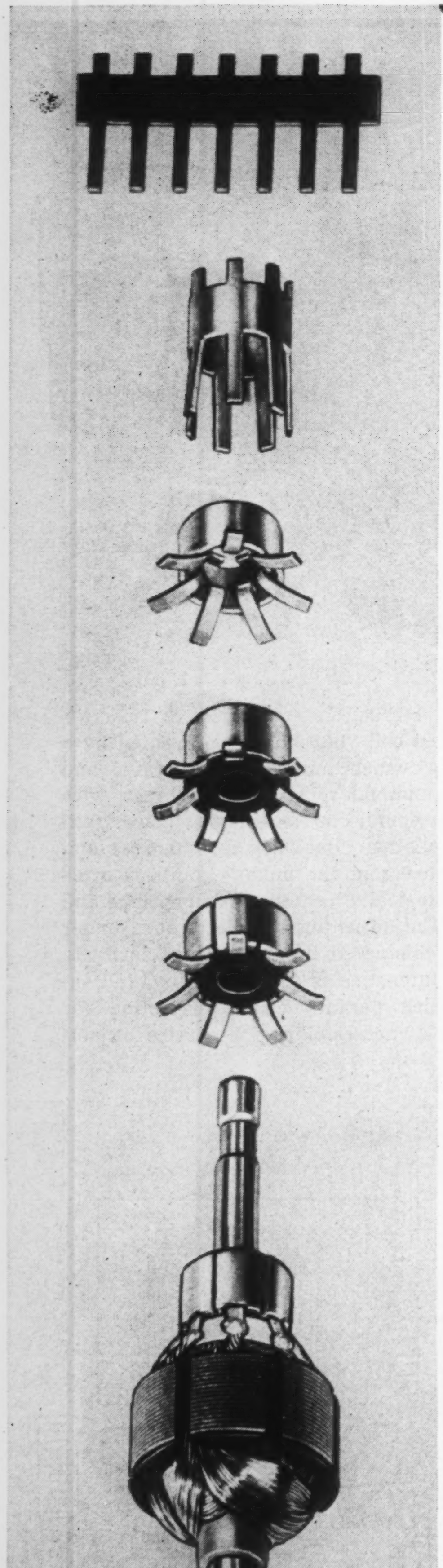
IDEAS



ACCURATE SYNCHRONIZING for engagement and release of brake friction surfaces is obtained with a clever linkage system in a solenoid-actuated drum brake design developed by Westinghouse Electric Corp. Geometry of the system assures equal distribution of pressure at two opposed brake shoes and compensates automatically for drum misalignment and normal wear.

In operation, the brake is spring engaged and solenoid released. Brake torque, magnet travel and brake shoe clearance are controlled through a single spindle adjustment, eliminating three separate adjustments required in a previous design. Solenoid coil "burnout" is prevented by a retarding bar which limits magnet travel and also permits manual release of the brake with the adjusting spindle in the event of power failure or for relining. Backlash due to wear and reversal of thrust in the linkage joints is overcome by strategically located tension springs and tendency of the adjusting spindle to turn under vibration is eliminated by two spring clips. In addition, maintenance is facilitated by the construction which permits visual inspection for wear and easy accessibility for service adjustments.

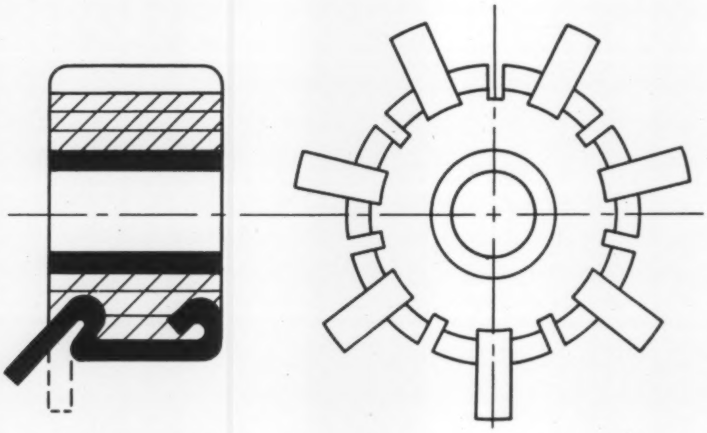


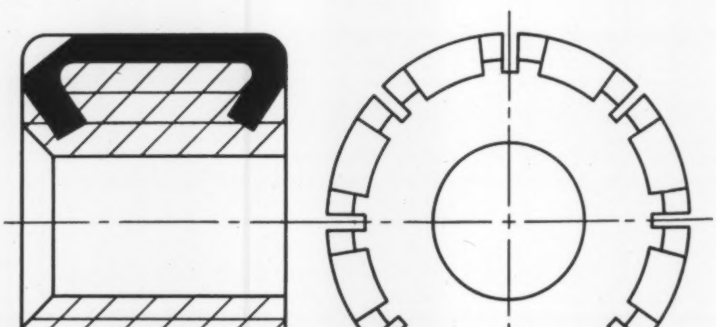


IDEAS

MOLDED COMMUTATOR ASSEMBLIES of metal and plastic simplify production of small, intricate units and offer flexibility in meeting design requirements. High producibility is achieved through a progressive assembly sequence in which the metal is blanked, formed and anchored to a plastic core. Undercutting finally separates the solid shell into the required number of individual segments.

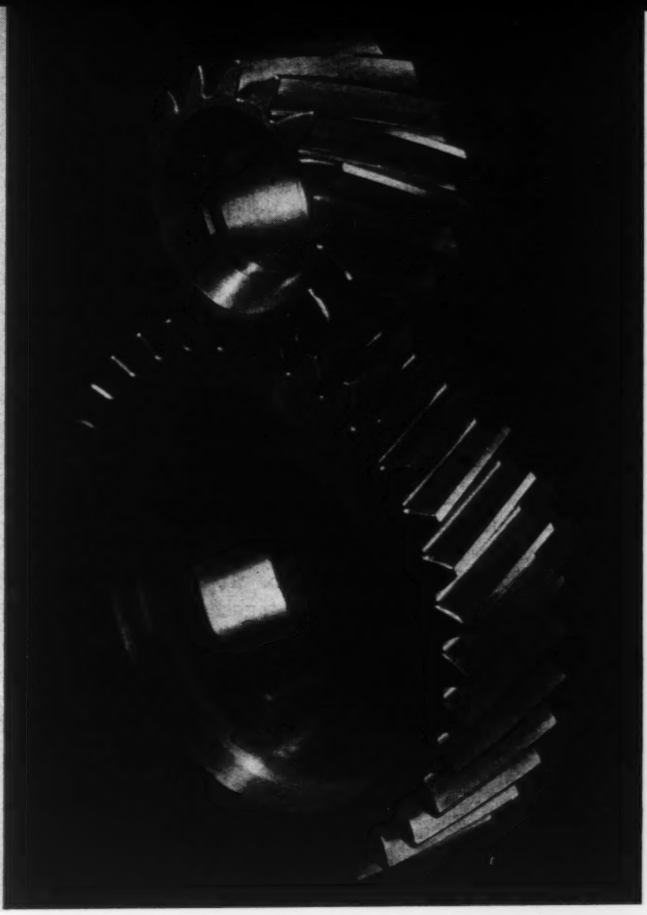
Developed by Midwest Molding and Mfg. Co., molded electric motor commutator designs have been produced in sizes from 7/16 to 1 3/16 inches in diameter and varying in number of segments from 7 to 24. The shells are generally formed from 0.042-inch thick electrolytic copper sheet, with or without silver content, and are blanked with lugs which are turned under for anchoring into the thermosetting plastic core. Concentricity is held to within plus or minus 0.005-inch and bore size is held to within plus or minus 0.002-inch without bushing, or plus or minus 0.001-inch with bushing. Wire connections are made to the segments by means of slots or prong extensions.





Dynamic Loads on Gear Teeth

. . . a rational method for computing the dynamic increment from known design factors



By W. A. Tuplin
Professor of Applied Mechanics
University of Sheffield
Sheffield, England

TORQUE that may be safely applied to a gear in mesh with another is smaller for high speeds than for low speeds. The chief reason is that the actual load exerted by one tooth on another is that corresponding to the external torque applied to the gear shaft plus a dynamic increment dependent upon errors of pitch between the teeth concerned and their neighbors and upon the rotational speed of the gears. The load that may safely be imposed on the tooth surfaces depends, among other things, on the number of times for which it is to be applied during the expected life of the gear. From this load the dynamic load must be subtracted to give the load corresponding to the safe external torque.

Owing to the high speed of propagation of stress waves in steel and other gear materials, it is unlikely that, even at the highest gear speeds attained or contemplated, the distribution of gear tooth stresses for any phase of contact differs appreciably from that in the static condition. Also, so far as is known, speed of application of load has no effect on the number of applications required to cause failure of any given material. The effect of speed on allowable external torque on a gear therefore appears to be solely that of the dynamic load and this is therefore the factor to be investigated in considering the question of allowable nominal loads at high speeds.

Effect of High-Tooth: In a pair of high-speed gears, the passage of a "high tooth" through the meshing zone is equivalent to the rapid insertion of a thin wedge between loaded teeth of stationary gears. If such gears could be rigidly held, the insertion of the wedge would have to be accommodated by additional

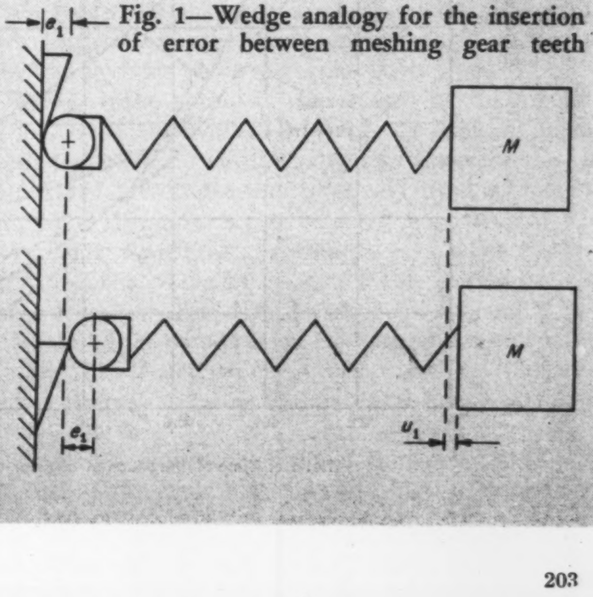


Fig. 1—Wedge analogy for the insertion of error between meshing gear teeth

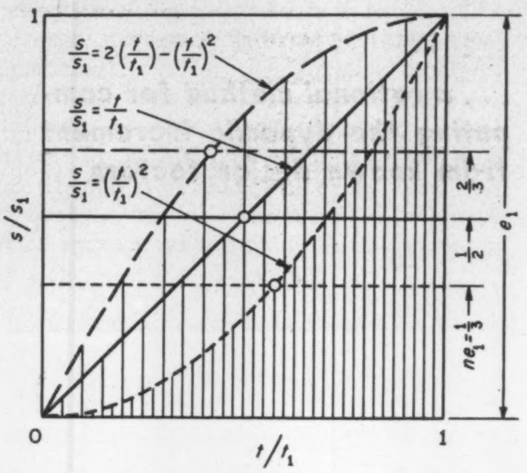
deflection of the loaded teeth. If, on the other hand, the gears are not held, and the wedge is inserted slowly, the gears suffer relative angular displacement and the tooth deflection caused by the wedge is negligible. The first case corresponds to that of gears running extremely fast; the loaded teeth suffer a total dynamic deflection equal to the error and the corresponding load is the dynamic increment. The second case corresponds to that of gears running extremely slowly and the dynamic increment is zero.

The terms "extremely fast" and "extremely slow" have in themselves no precise meaning, but the following analysis produces one for them.

The dynamic system to be examined consists of the two gears each rotatable about its axis and coupled by the engaging teeth so long as the load between them does not fall to zero. It is thus an angularly vibrating system with two masses elastically connected by the engaging teeth held in contact by the external torques. If each gear is in the form of a solid disk with grooves, the elasticity is that of the teeth loaded at any particular instant. The remaining parts suffer no comparable distortion and so may be regarded as rigid masses. If, on the other hand, a gear is in the form of a thin toothed rim, the bulk of the rotational inertia is contained in the rim, but its elasticity may well exceed that of the teeth and must therefore be taken into account.

The motions and loads induced by the insertion of a wedge between two parts of the elastic element may be determined from a solution of the conventional differential equation for forced harmonic motion but a simpler analysis suffices to estimate the maximum force, and this is the essential feature for the present purpose.

Fig. 2—Representations of the three types of wedge errors



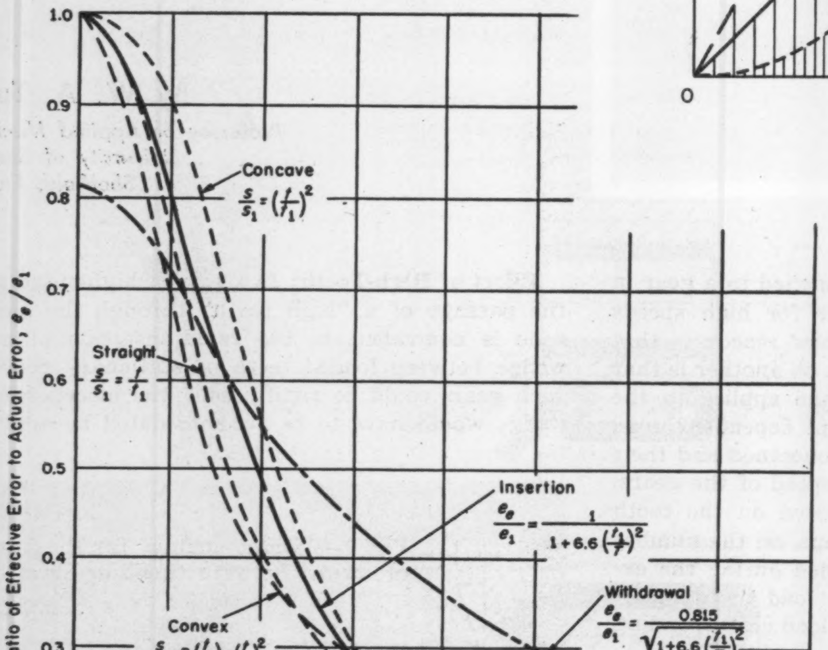


Fig. 3—Curves for various modes of introduction of error

The simplest case is that in which one of the masses is infinitely large and a further simplification is to imagine the other mass as having straight-line motion under the influence of a compression spring, *Fig.* 1. The wedge is inserted in time t_1 and the left-hand end of the spring is thus displaced by a distance e_1 in that time. The mean displacement during that period may be written as ne_1 where n is a fraction, less than unity, determined by the shape of the wedge and the variation of its velocity during the interval t_1, *Fig.* 2. For a wedge of uniform taper, moving with uniform velocity, $n = \frac{1}{2}$. A more severe action is produced by a concave wedge, for which n is less than $\frac{1}{2}$. A convex wedge is gentler, (because the taper is least when the load is greatest) and for this form, n is greater than $\frac{1}{2}$.

The displacement of the mass during time t_1 is u_1 and the maximum compression of the spring is therefore $e_1 - u_1$. In the following discussion, it is assumed that the mean compression of the spring during the time t_1 is $n(e_1 - u_1)$. If the mass is M and the stiffness of the spring is k, the mean acceleration a of the mass is $kn\ (e_1 - u_1)/M$. If this be assumed to have the same effect as a constant acceleration of the same amount, the displacement u_1 of the mass during time t_1 from rest is

$$u_1 = \frac{a\,t_1^2}{2}$$

or

$$u_1 = e_1 - (e_1 - u_1) = \frac{n\,k}{2\,M}\,(e_1 - u_1)\,t_1^2$$

Hence

$$e_1 - u_1 = \frac{e_1}{1 + \dfrac{n\,k}{2\,M}\,t_1^2}$$

Now if T is the period of natural vibration of the mass M under the influence of a spring of stiffness k,

$$T = 2\pi\sqrt{\frac{M}{k}}$$

and so

$$\frac{k}{M} = \left(\frac{2\pi}{T}\right)^2$$

Hence

$$\frac{e_1 - u_1}{e_1} = \frac{1}{1 + 2\,n\,\pi^2\left(\dfrac{t_1}{T}\right)^2}$$

and the maximum force in the spring which is $k(e_1 - u_1)$ is equal to

$$F_1 = \frac{k\,e_1}{1 + 2\,n\,\pi^2\left(\dfrac{t_1}{T}\right)^2} \quad \text{.......................} (1)$$

From Equation 1 it is seen that the maximum value of F_1 in any given system occurs in the case of $t_1 = 0$. This maximum value is ke_1 which means that the inserted wedge of maximum thickness e_1 has its full effect.

If t_1 is large compared with T, the value of F_1 is a small fraction of ke_1. For extremely slow insertion, $F_1 = 0$.

Because high-precision involute gear teeth are normally generated by straight-edged cutters or by flat grinding wheels, the most severe type of profile error is the occurrence of a flat much wider than the almost imperceptible ones produced by a generating machine in perfect order. The engagement of a flat on one tooth profile with the normally curved mating profile is equivalent, during the second half of the engagement period, to the insertion of a wedge for which $n = \frac{1}{3}$. If this factor is accepted as the worst likely condition, Equation 1 becomes

$$F_1 = \frac{k\,e_1}{1 + 6.6\left(\dfrac{t_1}{T}\right)^2} \quad \text{.......................} (2)$$

The quantity by which k is multiplied in the right hand side of Equation 2 may be called the *effective error*, $e_e = e_1/[1 + 6.6(t_1/T)^2]$, for an *actual error*, e_1. Then

$$\frac{e_e}{e_1} = \frac{1}{1 + 6.6\left(\dfrac{t_1}{T}\right)^2} \quad \text{.......................} (3)$$

which is plotted in *Fig.* 3 along with corresponding (dotted) curves calculated from solutions of the differential equations for three types of wedge (three modes of inserting error):

1. Uniform taper, $s/s_1 = t/t_1$
2. Concave circular arc, $s/s_1 = (t/t_1)^2$
3. Convex circular arc, $s/s_1 = 2(t/t_1) - (t/t_1)^2$

As *Fig.* 3 shows, Equation 3 is a good average representation of the results of rigorous calculation and in view of the impracticability of measuring (much less of predicting) all the details of distribution of pitch errors in gear teeth, it may reasonably be accepted as the basis of a method of estimating dynamic tooth loading.

Effect of Low Tooth: The principles already described may be applied to estimate the effect of transfer of load from one tooth to another with pitch error such that the driven gear thereupon lags behind its previous position relative to the driving gear.

In *Fig.* 4 the spring is compressed by the amount s_o under the steady load ks_o and the effect of introduction of a negative pitch error of magnitude e_1 is reproduced by withdrawing the wedge by this amount.

Let the displacement of the left-hand end of the spring after time t be s, so that $s = e_1$ when $t = t_1$. Let the mean value of s during this period be ne_1 where n is less than 1. Let the displacement of the mass during the same period have instantaneous value u after time t and value u_1 after time t_1. Let the mean value of u during this period be mu_1 where m is less than 1.

The mean change in length of the spring is $ne_1 - mu_1$ and so the mean force accelerating the mass from right to left is $k\ (ne_1 - mu_1)$. Hence

$$u_1 = \frac{k}{2M}\,(ne_1 - mu_1)\,t_1^2$$

whence, writing $k/M = (2\pi/T)^2$,

$$u_1 = \frac{ne_1}{2\left(\dfrac{T}{2\pi t_1}\right)^2 + m} \quad \text{.......................... (4)}$$

If t_1/T is very small the force ks_0 is unable to move the mass appreciably during the time t_1 and so $u_1 = 0$ irrespective of the values of n and m.

It t_1/T is very large, the withdrawal of the wedge is very slow, inertia effects are therefore negligible and so $u_1 = e_1$. As Equation 4 shows that in this case, $u_1 = ne_1/m$, it follows that $n = m$ for large values of t_1/T. As this does not conflict with the circumstances when t_1/T is very small, it is reasonable to write $n = m$ in general.

At time t_1 the left-hand end of the spring comes to rest, but the mass has a right-to-left velocity which diminishes to zero while the spring is compressed by an additional amount c. During the displacement $u_1 + c$ the steady force ks_0 does an amount of work $ks_0(u_1 + c)$. This is equal to the increase in strain energy of the spring from the initial condition (compression s_0) to the final condition (compression $s_0 + u_1 + c - e_1$) plus the work done on the withdrawing wedge, equal to the mean force on the wedge $[ks_0 - k\,(ne_1 - nu_1)]$ multiplied by the displacement e_1. Hence

$$ks_0\,(u_1 + c) = \frac{k}{2}\,[(s_0 + u_1 + c - e_1)^2 - s_0^2] + ke_1\,[s_0 - n\,(e_1 - u_1)]$$

Writing $s_0 + u_1 + c - e_1 = z$ gives

$$2\,s_0\,[z - s_0 + e_1] = z^2 - s_0^2 + 2\,e_1\,[s_0 - n\,(e_1 - u_1)]$$

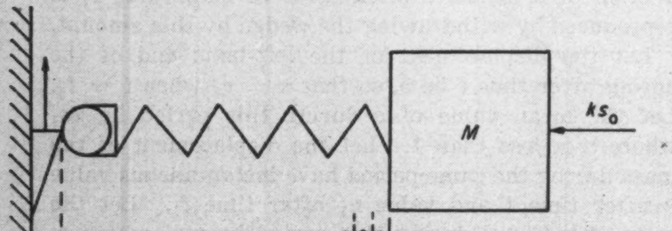
whence

$$\frac{z^2}{s_0^2} - \frac{2z}{s_0} + 1 - 2\,\frac{ne_1}{s_0}\left(\frac{e_1}{s_0} - \frac{u_1}{s_0}\right) = 0 \quad \text{. . . (5)}$$

and

$$\frac{z}{s_0} = 1 \pm \frac{e_1}{s_0}\sqrt{2\,n\left(1 - \frac{u_1}{e_1}\right)}$$

Fig. 4—Wedge analogy for the withdrawal of error between gear teeth



Hence, neglecting the alternative negative sign, maximum force in the spring is

$$kz = ks_0 + ke_1\sqrt{2\,n\left(1 - \frac{u_1}{e_1}\right)}$$

The quantity ks_0 is the steady load and so the dynamic increment per inch width is

$$ke_1\sqrt{2\,n\left(1 - \frac{u_1}{e_1}\right)}$$

or

$$F_1 = ke_1\sqrt{\left[1 - \frac{n}{2\left(\dfrac{T}{2\pi t_1}\right)^2 + n}\right]2n}$$

$$= ke_1\sqrt{\frac{2\,n}{1 + 2\,n\,\pi^2\left(\dfrac{t_1}{T}\right)^2}} \quad \text{.............. (6)}$$

Taking $n = 1/3$,

$$F_1 = ke_1\sqrt{\frac{0.67}{1 + 6.6\left(\dfrac{t_1}{T}\right)^2}} \quad \text{................ (7)}$$

or, by analogy with Equation 3, the ratio of effective error to actual error is

$$\frac{e_e}{e_1} = \frac{0.815}{\sqrt{1 + 6.6\left(\dfrac{t_1}{T}\right)^2}} \quad \text{.................... (8)}$$

Values of the quantity represented by Equation 8 are given by the chain-dotted curve in *Fig.* 3. This intersects the curve representing Equation 3 at the ordinate $t_1/T = 0.3$. To take care of the more difficult condition in each case the full curve is used for values of t_1/T less than 0.3 and the chain-dotted curve for higher values.

For design purposes the combination of the curves for Equations 3 and 8 may be used and this is reproduced for convenience in *Fig.* 5. It is seen that when the time of inserting the error is equal to the natural period of vibration, the effective error is about 0.3 times the actual error. So far as dynamic loading is concerned, gears may be regarded as "fast" if the time of insertion of an error is less than about 0.3 times the natural period, or "slow" if the ratio exceeds 2.

From the foregoing development (Equations 2 & 3, 7 & 8), the equations for dynamic increment (force) reduce to

$$F = k_T\,e_e \quad \text{.................................. (9)}$$

where k_T is the stiffness of a two-gear system and e_e is the effective error as determined from the appropriate point on the curve of *Fig.* 5.

Succession of Pitch Errors: In the foregoing, an estimate has been made of the dynamic load induced by an isolated pitch error. Although the effect of any such discontinuity in motion is to cause vibratory loading that dies away under damping influences, this effect has been ignored, because the greatest load is the first maximum after the error begins to take effect.

If a second error comes into action before the effect of the first one has died away, the conditions are more difficult to analyze and it is possible that the maximum dynamic load may exceed either of those due to one error alone. In particular if a series of errors were to take effect at time intervals equal to a natural period of vibration of the dynamic system, their loading effect might become very large because of resonance.

However, this extreme condition is unlikely, because in gears of quality appropriate to high speeds the errors are small and are random in character.

In all gears, however, there is one discontinuity of fixed frequency at any given running speed, and that is the succession of tooth engagements. Resonance therefore occurs when the frequency of tooth engagement is equal to a natural frequency of the system. It is not known to the author whether such resonance has ever induced troublesome tooth loading and it seems unlikely because of the common use of the helical tooth form in high speed gears. With that type of tooth, irregularity of loading due to tooth engagement affects only a small fraction of the face width at the leading ends of the tooth helices and so the forces that might maintain a resonant vibration are extremely small.

In the case of straight-tooth spur gears, resonant vibration at the frequency of tooth engagement is more likely, but it must be remembered that if the vibratory loading is great enough to cause tooth separation the natural frequency is reduced by an amount dependent on the backlash and so resonance in the ordinary sense disappears.

Numerical Details: Using the foregoing analysis for estimating the dynamic loading on gear teeth requires knowledge of (1) the natural period of angular vibration of the gears; (2) the magnitude of the pitch error; and (3) the time in which each error takes effect.

It is clearly desirable that the procedure should be

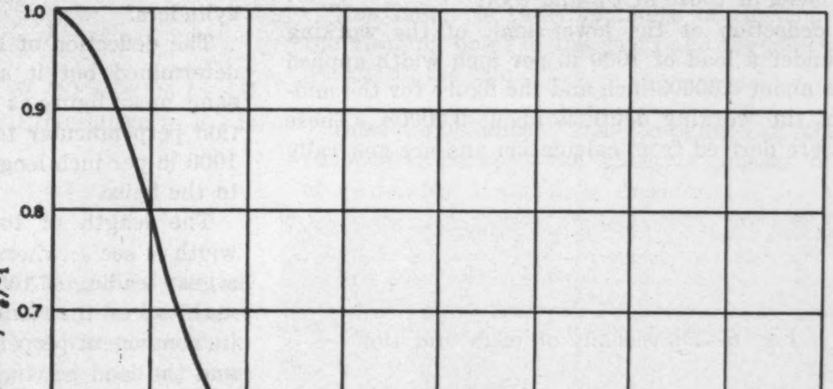


Fig. 5—Design curve for finding the ratio of effective error to actual error from the ratio of time consumed by introduction of error to natural period of vibration

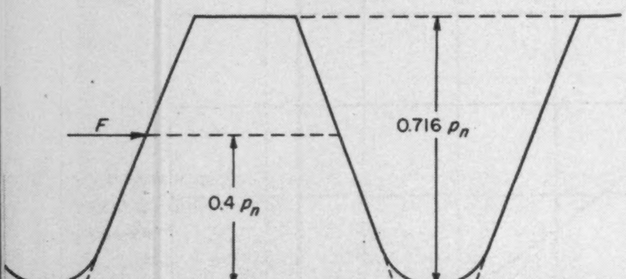
capable of reduction to a convenient working formula based on easily ascertainable dimensions of the gears. Because of uncertainties about the exact values and the nature of pitch errors, there is no object in seeking high precision in determining stiffnesses or moments of inertia.

Stiffness and Compliance: Because the elements that yield under the transmission of a force from one gear to the other are loaded in series, it is more convenient to think of the compliance (the reciprocal of the stiffness) of each element, because the compliance of the assembly of loaded members is the sum of the compliances of the individual members.

Compliance of Teeth: Taking as a basis a steel rack tooth of 20-deg normal pressure angle with a depth equal to 0.716 times the normal pitch, and with tooth thickness equal to half the pitch at depth equal to 0.318 times the pitch, with a load of 1000 lb per inch width acting perpendicular to the tip in the plane of the tips, the tip deflection is about 0.0003-inch irrespective of pitch. This figure is a calculated one and is the sum of the deflection due to bending, (assuming the same second moment of area at all sections, equal to the mean of those at tip and root) and that due to shear assuming a uniform cross-sectional area, equal to the mean of those at tip and root.

The deflection at the lower limit of the working depth under a load of 1000 lb per inch width applied there is about 0.00003-inch and the figure for the midpoint of the working depth is about 0.00008. These figures are derived from calculation and are generally confirmed by actual test.

Fig. 6—Dimensions of teeth and rim



Now tip loading on a tooth of one gear means that the mating tooth is loaded near the root. Mid-depth loading on one tooth is mid-depth loading on the other tooth. In the case of spur gears tip-and-root loading means that the total load is divided between two pairs of teeth; mid-depth loading is concentrated on one pair of teeth. The total deflection in inches of two teeth under a total nominal load of 1000 lb per inch width is therefore approximately:

Deflected Tooth	Contact on Tooth No. 1 at Tip	Mid-depth	Root
No. 1	0.00015	0.00008	0.000015
Mating	0.000015	0.00008	0.00015
Total	0.000165	0.00016	0.000165

The difference between the deflection figures for the two types of contact is thus small. When single-pair contact occurs on one tooth at the highest possible point (determined by measuring a distance equal to the base pitch along the line of action from the tip-circle of the mating tooth) the total deflection is of the order of 0.00021-inch. As a general mean figure, remembering that the average gear tooth is, owing to its curved profiles, rather less rigid than a rack tooth, 0.0002-inch may be taken as the deflection of spur gear teeth under a nominal load of 1000 lb per inch width along the common tangent plane to the pitch cylinders.

The deflection of helical gear teeth is not so easily determined but it appears reasonable to accept the same mean figure as for spur gears to represent deflection perpendicular to the tooth helix under a load of 1000 lb per inch length of tooth, applied perpendicular to the helix.

The length of tooth corresponding to unit axial width is sec ψ, where ψ is the helix angle. Hence, for a gear loading of 1000 lb per unit axial width, the normal load on that length of helix is 1000 sec ψ (because its component perpendicular to the axis must be 1000) and the load per inch length of helix is 1000 lb. For a normal deflection of 0.0002-inch the deflection measured perpendicular to the axis is 0.0002 sec ψ.

These figures apply to steel, for which the modulus of elasticity is 30,000,000 psi. Generalizing for a pair of teeth of materials with moduli E_1 and E_2, the deflection for a nominal load of 1 lb per inch of axial width is

$$\frac{1}{k_t} = 3\left(\frac{1}{E_1} + \frac{1}{E_2}\right) \sec \psi \text{ inches}$$

This is the expression for the compliance of the pair of teeth in inches at the pitch circle for a tangential force of 1 lb per inch of axial width.

Elastic flattening of tooth surfaces is so small compared with the other compliances that it is neglected in this article.

Compliances of Tooth and Rim: In the case of a gear in the form of teeth cut in a thin rim, two extra compliances need consideration.

A tooth cut in a thin rim is not "built-in" to the mass of the gear, since its root-fixing is not the rigid one assumed in the calculation of tooth deflection as already described. The bending moment at the root of the tooth causes the part of the rim immediately below the tooth to suffer angular displacement relative to the remainder of the rim, and the tooth has extra compliance on that account.

Also, the rim suffers circumferential strain because of transmission of dynamic load from the teeth to the mass of distant parts of the rim.

Fixing of Tooth in Rim: The compliance of this feature is difficult to estimate accurately. It is arbitrarily assumed that tilt of the rim under the particular tooth concerned is due to radial shear deformation in the adjoining rim-sections of minimum thickness, *ABCD* and *EFGH* in *Fig.* 6.

Taking the case of a spur gear with load applied at the mid-point of the working depth, the moment of the force F about the axis at O is $F(0.4\,p_n + 0.5\,h)$. This is assumed to be balanced by equal and opposite vertical shear forces in the planes of BC and EH, the magnitude of each being

$$\frac{F\,(0.4\,p_n + 0.5\,h)}{0.8\,p_n} = F\left(0.5 + 0.625\,\frac{h}{p_n}\right)$$

Taking F as being the force per unit width, the shear stress in all vertical sections (depth h) between AD and BC and between EH and FG is

$$F\left(\frac{0.5}{h} + \frac{0.625}{p_n}\right)$$

Hence, the upward movement of BC relative to AD and the downward movement of EH relative to FG is

$$\frac{F}{C}\left(\frac{0.5}{h} + \frac{0.625}{p_n}\right)0.2\,p_n$$

where C = modulus of rigidity.

The tilt of the prism *BEHC* relative to FG and BC is this movement divided by ½ CH and the associated horizontal movement of the tooth at the point of application of F is the tilt multiplied by $0.4\,p_n$ since B and E have no horizontal movement associated with this compliance. Hence the compliance is

$$\frac{1}{k_r} = \frac{1}{C}\left(0.1\,\frac{p_n}{h} + 0.125\right) = \frac{1}{C}\left(\frac{0.1}{a} + 0.125\right)$$

where a is the ratio of the thickness of rim below root of teeth to the normal pitch of the teeth. In the case of a helical gear, the expression for compliance is multiplied by $\sec\psi$.

Circumferential Compliance of Rim: *Fig.* 7 represents the circumference of a toothed rim subjected to a tangential force F per unit width at A. Rotation is prevented by the tangential force F per unit width at B. Let x = circumferential movement of A relative to B in consequence of stretch of the arc AB and compression of the arc ACB.

The effective radial depth of the rim in respect to circumferential strain is something greater than h because of the stiffening effect of the teeth. This is difficult to determine but may be about $h + 0.2\,p_n = (a + 0.2)\,p_n$, where $a = h/p_n$. The tensile force in AB per unit width is the product of strain, effective depth and modulus of elasticity, or

$$\frac{x}{AB}\,(a + 0.2)\,p_n E = \frac{x}{\theta}\,\frac{(a + 0.2)\,p_n E}{r}$$

The compressive force in ACB per unit width is given by a corresponding expression and the sum of the two forces is equal to F. Hence

$$F = \frac{x\,(a + 0.2)\,p_n E}{r}\left(\frac{1}{\theta} + \frac{1}{2\pi - \theta}\right)$$

The compliance of the rim for unit loading at points separated by angle θ is thus

$$\frac{r}{(a + 0.2)\,p_n E}\,\frac{\theta\,(2\pi - \theta)}{2\pi}$$

The mean value for all values of θ (0 to π) is

$$\frac{1}{k_c} = \frac{r}{2\pi\,(a + 0.2)\,p_n E}\,\frac{1}{\pi}\int_0 \theta\,(2\pi - \theta)\,d\theta$$

$$= \frac{\pi r}{3(a + 0.2)\,p_n E} = \frac{N\sec\psi}{6(a + 0.2)\,E}$$

where N = number of teeth in the rim.

This factor is the compliance of the rim between the meshing point of the gears and the effective mass center of the rim.

Total Compliance: The compliance of the elastic connection between the effective masses of a pair of gears, No. 1 and 2, is therefore

$$\begin{aligned}\frac{1}{k_T} = {} & 3\left(\frac{1}{E_1} + \frac{1}{E_2}\right)\sec\psi + \\ & \frac{1}{C_1}\left(\frac{0.1}{a_1} + 0.125\right)\sec\psi + \\ & \frac{1}{C_2}\left(\frac{0.1}{a_2} + 0.125\right)\sec\psi + \\ & \frac{1}{6}\left[\frac{N_1}{(a_1 + 0.2)\,E_1} + \frac{N_2}{(a_2 + 0.2)\,E_2}\right]\times \\ & \sec\psi \qquad (10)\end{aligned}$$

Moments of Inertia: The moment of inertia of a gear about its axis may be taken to be that of a plain rim or cylinder of the same width and of diameter equal to that of the circle that defines the mid-point of the working depth. As a close approximation this may be taken to be the diameter of the pitch circle $(N\,p_n \sec\psi)/\pi$.

The equivalent mass concentrated at the circumference of the pitch circle is equal to the moment of inertia of the gear divided by the square of the radius of the pitch circle. For a steel gear of uniform axial width at all radii, the equivalent mass per inch width is

$$M_1 = \frac{0.28\,\pi\,r^2}{2g} = \frac{r^2}{880}\text{ in lb-in-sec units}$$

where r = pitch radius. For a steel rim, the equivalent mass per inch width is

$$M_2 = \frac{0.28}{386}\pi\,(r^2 - r_b^2)\left(\frac{r^2 + r_b^2}{2}\right)\frac{1}{r^2}$$

$$= \frac{(r^2 - r_b^2)\,(r^2 + r_b^2)}{880\,r^2} \text{ in lb-in-sec units}$$

where r_b = radius of bore.

For a solid gear, $r_b = 0$, because the inertia of the shaft is appropriately included. For a pinion rigidly connected to another gear (as may occur in a double-reduction train), the "equivalent mass" of the pinion is increased by an amount equal to the moment of inertia of the other gear divided by the square of the pitch radius of the pinion.

Rotors connected to gears by shafts of conventional diameters and lengths may be ignored because the compliance of such shafts is usually much greater than that of the teeth and so the effect of dynamic loading caused by pitch-errors is not transmitted to such rotors.

Pitch Errors: Departures from uniformity of spacing of gear teeth on any selected circle can be measured with adequate accuracy, and indeed gears are often required to have pitch errors not exceeding specified amounts. It is usual to quote figures for "tooth-to-tooth pitch error" between successive teeth and for "composite pitch error" which is the spacing error of teeth separated by at least one other tooth. For the purpose of estimating dynamic loads on the teeth, adjacent pitch errors are the more important and indeed spacing errors over even shorter intervals may be more important still. The concept of spacing error over an interval less than one pitch perhaps needs explanation.

Let A, B and C be successive teeth on one gear and A′, B′ and C′ the corresponding teeth on the mating gear. Let A and A′ be in driving contact at a certain instant and let the gears rotate with uniform speeds inversely proportional to their numbers of teeth until B occupies the original position of A. Then the separation of B and B′ is the difference between the error in pitch of A and B and that of A′ and B′. Some combinations of pitch error would cause interference of B and B′ if the assumed conditions could be imposed. In general, the mismatch of B and B′ is the algebraic difference of the pitch errors in AB and A′B′.

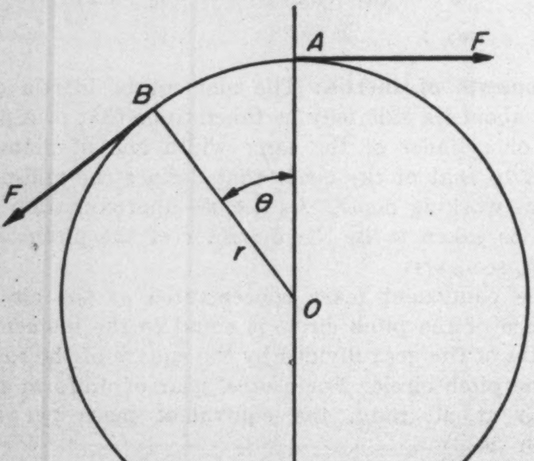


Fig. 7—Factors pertaining to stretch of rim

But mismatch can (and does) occur at any phase of engagement between the mentioned one which correspond to a particular position of the contact point on the path of contact. Mismatch in such other phases is the consequence of the combination of tooth-to-tooth pitch error as normally understood and profile error between the contact points and the points at which pitch error is measured.

The determination of errors in such detail as this is extremely laborious, and anticipation of their magnitudes in any contemplated gear is impossible. A reasonable course, for the purpose of design calculations is to take the sum of the maximum tooth-to-tooth pitch errors permitted in the gears concerned and to assume that an error of that magnitude takes effect in the time between engagement of successive pairs of teeth with a mode of insertion corresponding to $n = 1/3$, which is the most severe case likely to occur.

It has to be assumed that a pair of teeth with the greatest permitted pitch may mesh with a mating pair having the smallest permitted pitch. Consequently the error used in determining dynamic loads must be the sum of the greatest permitted departures of pitch from the nominal figure.

For spur or helical gears typical pitch-error figures, which may be used in estimating dynamic loading in the design stage, are

1. High precision, hobbed or ground: $0.0002 + 0.0002\,p_t$ inches.
2. High class commercial quality: $0.0004 + 0.0004\,p_t$ inches.
3. Average commercial quality: $0.0008 + 0.0008\,p_t$ inches.

where p_t = pitch in inches in plane perpendicular to axis.

The significant figure in this connection is the sum of the maximum pitch error of any two adjacent teeth in one gear and the corresponding figure for the other gear. Use of this sum is pessimistic, since if there is no common factor in the numbers of teeth in the mating gears, the maximum errors do not come together in every revolution of the pinion and so the fatigue effect of any one tooth is less than if they did. If the number of teeth in the wheel is exactly divisible by the number of teeth in the pinion, the maximum errors may never come together at all.

Example: The accompanying numerical problem presents the calculation sequence for estimation of the dynamic tooth loading of two double-helical steel gears at pitch-line speeds of 150 and 250 fps.

The calculated dynamic increment will not be applied to every tooth in the gear but it must be expected to act on some of them in addition to the load corresponding to the transmitted power. Consequently the external torque on the pinion must be limited so that any tooth is capable of taking the sum of the dynamic load and the power-transmitting load once in every revolution of the gear during its expected life. No other speed effect need be taken into account as the number of load cycles that any component may take before failure is independent of the time taken to complete them.

Justification of Approximations: The analysis used in this article is about as simple as is practicable. Approximations have been used where more nearly exact calculation, although possible, would be much more laborious. They have been used because the uncertainty about the nature and magnitude of pitch errors of gears that have still to be made renders an exact calculation procedure unjustifiable and also because the aim is to present a method that can reasonably be used in actual design. Long calculations are not likely to be employed in practice since designers often prefer a simple formula sanctioned by usage to an elaborate new one, however much more accurate it may be proved to be.

Example

Estimate the dynamic tooth loading of pitch-line speeds of 150 and 250 ft per sec for a pair of steel double-helical gears of the following specifications:

Number of teeth	75		615
Transverse pitch (in.)		0.815	
Normal pitch (in.)		0.7	
Tooth depth (in.)		0.5	
Normal pressure angle (deg)		20	
Tip diameter (in.)	20		160
Diameter of bore of rim (in.)			157
Possible adjacent pitch error in each gear (in.)		0.0008	

The calculation steps are:

1. Establish sec ψ.

$$\sec\psi = \frac{p_t}{p_n} = \frac{0.815}{0.7} = 1.164$$

2. Determine rim thickness of pinion (tip radius minus depth).

$$h_1 = \frac{20}{2} - 0.5 = 9.5 \text{ inches}$$

3. Determine rim thickness of gear (tip radius minus sum of depth and bore radius).

$$h_2 = \frac{160}{2} - 0.5 - \frac{157}{2} = 1.0 \text{ inch}$$

4. Calculate pinion and gear values for a.

$$a_1 = \frac{h_1}{p_n} = \frac{9.5}{0.7} = 13.6 \text{ and } a_2 = \frac{1.0}{0.7} = 1.43$$

5. Find total compliance and stiffness from Equation 10.

$$\frac{1}{k_T} = 3\,\frac{2}{30{,}000{,}000}\,1.164 + \frac{1}{12{,}000{,}000} \times \left(\frac{0.1}{13.6} + 0.125 + \frac{0.1}{1.43} + 0.125\right) 1.164 + \frac{1}{6(30{,}000{,}000)}\left(\frac{75}{13.8} + \frac{615}{1.63}\right) 1.164$$

$$= (0.233 + 0.032 + 2.5) \times 10^{-6}$$

$$= 2.77 \times 10^{-6}$$

$$k_T = \frac{1}{2.77 \times 10^{-6}} = 0.36 \times 10^{6}$$

6. Determine the equivalent masses at the pitch circles. Assume that tip radius minus pitch radius is equal to $p_n/\pi = 0.22$. Thus, for the pinion, the equivalent mass per inch width is

$$M_1 = \frac{r^2}{880} = \left(\frac{20-0.44}{2}\right)^2 \frac{1}{880} = 0.109 \text{ lb-in-sec}$$

For the gear, $r = (160/2) - 0.22 = 79.78$ inches and $r_b = 157/2 = 78.5$ inches. Its equivalent mass per inch width is

$$M_2 = \frac{(79.78^2 - 78.5^2)(79.78^2 + 78.5^2)}{880\,(79.78)^2}$$

$$= 0.45 \text{ lb-in-sec}$$

7. Determine the natural period for a system with two masses from

$$T = 2\pi\sqrt{\frac{1/\kappa_T}{\dfrac{1}{M_1} + \dfrac{1}{M_2}}}$$

$$= \frac{2\pi}{10^3}\sqrt{\frac{2.77}{\dfrac{1}{0.109} + \dfrac{1}{0.45}}}$$

$$= 0.00307 \text{ sec}$$

8. Find the time for one pitch and the ratio of this time to the natural period. For 150 fps, $t_1 = 0.815/150\ (12) = 0.00045$ sec and $t_1/T = 0.00045/0.00307 = 0.15$. For 250 fps, $t_1 = 0.815/250\ (12) = 0.000272$ sec and $t_1/T = 0.000272/0.00307 = 0.089$.

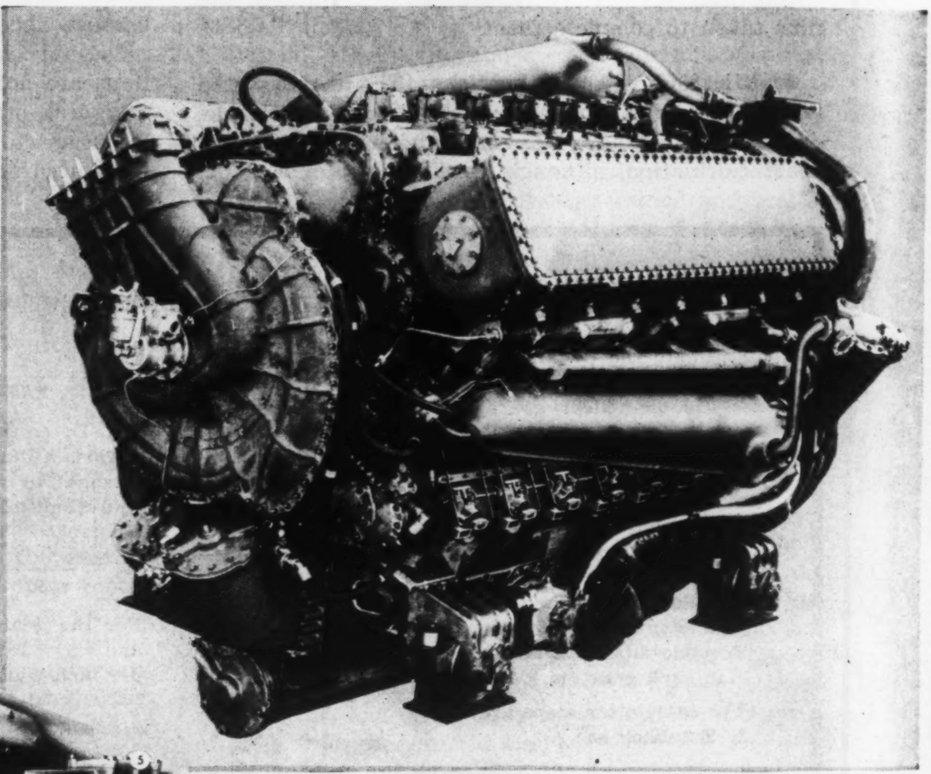
9. Find the effective error. For 150 fps, from the curve in *Fig.* 5, $e_e/e_1 = 0.87$ for $t_1/T = 0.15$. Since the actual error, the sum of tooth-to-tooth pitch errors of both gears, is $0.0008 + 0.0008 = 0.0016$-inch, effective error $e_e = 0.87\ (0.0016) = 0.00139$-inch. Similarly for 250 fps, $e_e/e_1 = 0.95$ and $e_e = 0.95(0.0016) = 0.00152$-inch.

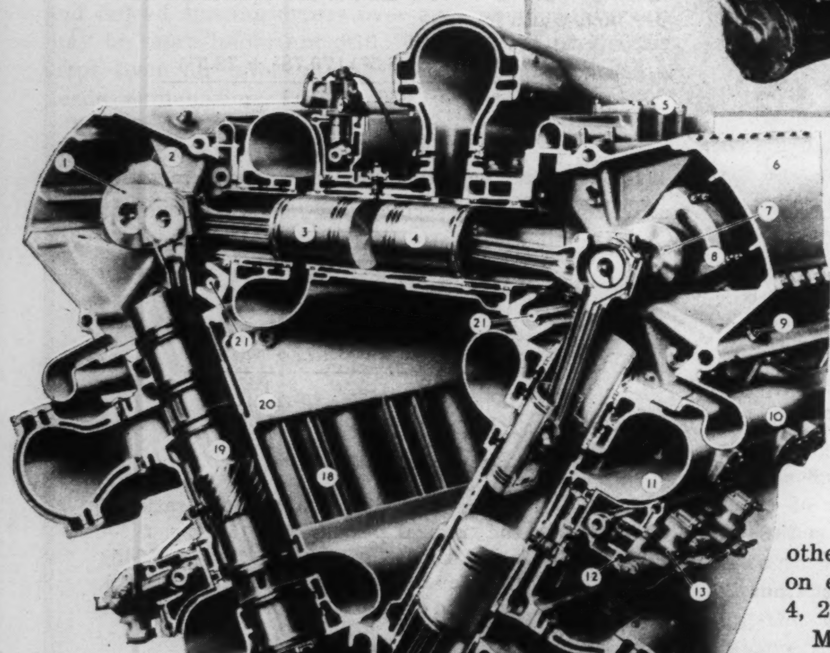
10. Calculate the dynamic increment from Equation 9. For 150 fps, $F = 0.00139\ (0.36 \times 10^6) = 500$ lb per inch. For 250 fps, $F = 0.00152(0.36 \times 10^6) = 547$ lb per inch.

CONTEMPORARY DESIGN

Marine Diesel Has Triangular Cylinder Arrangement

OPERATING on a two-stroke cycle and utilizing opposed pistons, the Deltic marine diesel engine has cylinders arranged in a triangle, thus giving smoothness in running, equalizing crankshaft loading, and permitting an efficient porting layout for scavenging and cylinder charging. Maximum shaft horsepower of the 18-cylinder engine developed by D. Napier and Son Ltd., London, England, is 2500 horsepower at 2000 rpm, with a continuous rating of 1875 horsepower at 1700 rpm.





WITH THE CYLINDERS in an equilateral triangle, a phase-angle difference of 20 degrees exists between exhaust and inlet crankshafts. This phase displacement, with the exhaust crankshaft leading, gives efficiency in porting. Each crankpin carries one intake and one exhaust piston, so that the loading on each crankpin and the power transmitted through each crankshaft are identical. With the triangular arrangement, one crankshaft (in practice the bottom one) must rotate in the opposite sense from the other two. The 18-cylinder engine, with six cylinders on each crankshaft firing in normal order (1, 5, 3, 4, 2, 6), has equal firing intervals of 20 degrees.

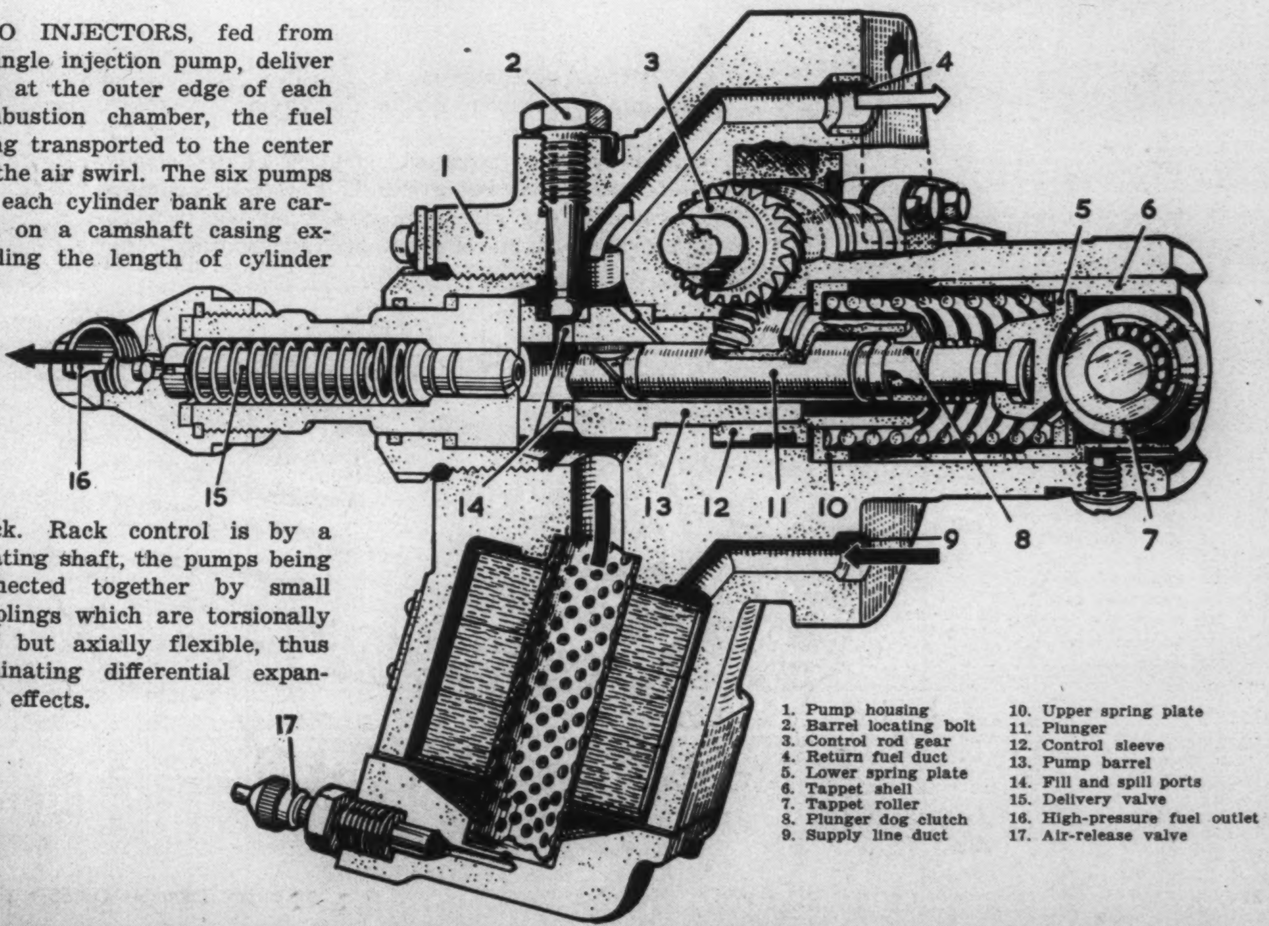
Main body of the engine is built up from three identical cast-aluminum 6-cylinder blocks, and cast-aluminum crankcases. High-tensile steel tie-bolts extend from each crankcase through the cylinder block to the other crankcase. These bolts carry all combustion loads, the cylinder blocks remaining in compression.

1, 7, 17. Crankshafts
2, 6. Crankcases
3. Intake piston
4. Exhaust piston
5. Crankcase breather
8. Main bearing cap
9. Crankcase tiebolt
10. Drain oil manifold
11. Air intake manifold
12. Camshaft casing
13. Fuel injection pump
14. Exhaust manifold
15. Sea-water pump
16. Fresh-water pump and pressure oil pump drive gear
18. Cylinder-block tiebolts
19. Cylinder liner
20. Cylinder block
21. Blower flexible driveshafts

WET TYPE cylinder liners are machined from hollow steel forgings, the liners are chrome plated and finished by lapping. Water seals are flexible rubber members. Intake ports around the whole circumference of the liner are machined in a partially tangential direction, thus imparting a "swirl" to intake air for efficient fuel-air mixing and scavenging. Exhaust ports are located around approximately one-half the circumference.

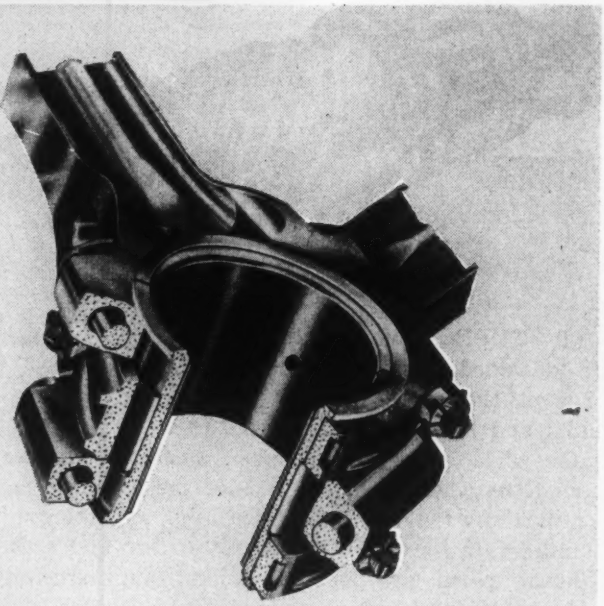
PATENTED PISTONS are in two parts held together by a retaining ring. The inner member, machined from a forging, carries the hardened-steel gudgeon pin, while the outer member is cast aluminum having a continuous skirt and containing a cast-in austenitic-iron insert that carries the two top piston rings. An annular chamber between the parts carries oil for cooling.

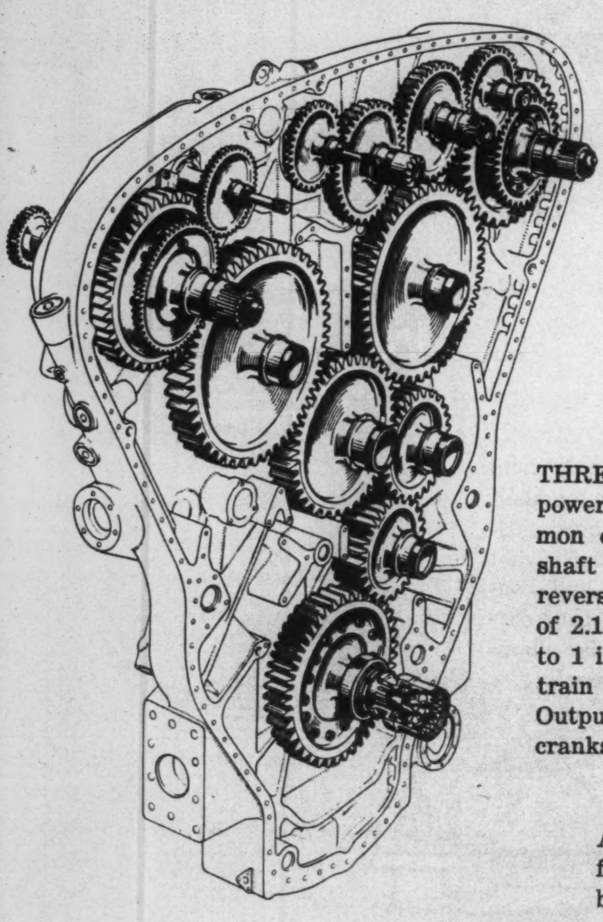
TWO INJECTORS, fed from a single injection pump, deliver fuel at the outer edge of each combustion chamber, the fuel being transported to the center by the air swirl. The six pumps for each cylinder bank are carried on a camshaft casing extending the length of cylinder block. Rack control is by a rotating shaft, the pumps being connected together by small couplings which are torsionally stiff but axially flexible, thus eliminating differential expansion effects.



1. Pump housing
2. Barrel locating bolt
3. Control rod gear
4. Return fuel duct
5. Lower spring plate
6. Tappet shell
7. Tappet roller
8. Plunger dog clutch
9. Supply line duct
10. Upper spring plate
11. Plunger
12. Control sleeve
13. Pump barrel
14. Fill and spill ports
15. Delivery valve
16. High-pressure fuel outlet
17. Air-release valve

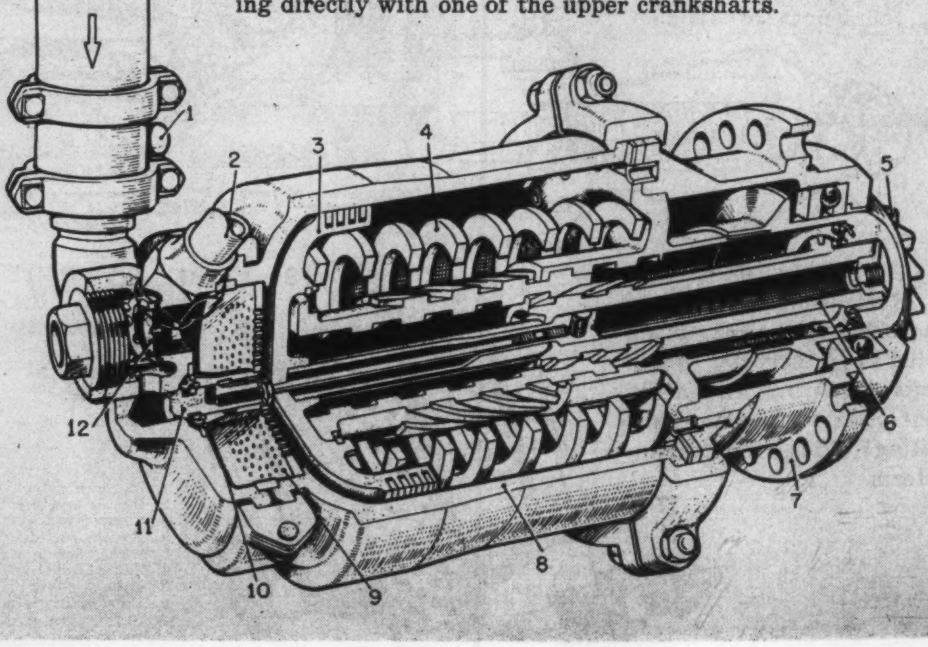
CRANKPIN CONNECTING RODS are the fork and blade" type, with one rod fitting inside the other. Bearing surfaces are steel-strips, lead-bronze lined and lead plated. Both rods are drilled to feed oil for piston cooling.





THREE CRANKSHAFTS are coupled together with the power from each crankshaft being transmitted to a common output shaft at the center of the triangle. Output shaft runs at slightly above the crankshaft speed; a reverse and reduction-gear system provides gear ratios of 2.106 to 1 for forward drive to the propeller and 2.397 to 1 in reverse. Each crankshaft is connected to the gear train by a splined connection to a flexible quill shaft. Output shaft rotation can be reversed without reversing crankshaft rotation by replacing the idler-gear assembly.

A COMBUSTION starter, in which a cartridge is fired into a cylinder, starts the engine. A rotary breech carries five cartridges, electrically fired. The cylinder contains a piston mounted on a helically splined shaft carrying a Bendix type claw coupling. The coupling engages a similar one on a gear meshing directly with one of the upper crankshafts.



1. Governor connection
2. Exhaust outlet
3. Piston
4. Return spring
5. Clutch jaw
6. Main drive shaft
7. Mounting flange
8. Cylinder body
9. Perforated disk
10. Combustion chamber
11. Exhaust valve
12. Safety disk

What You Should Know About the NEW PATENT LAW

By H. A. Toulmin Jr.
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After four years of hearings, Congress recently passed a new Patent law about which there is considerable controversy. Some features of the new law, including those relating to standards of invention, are described in the Senate committee report as merely clarifying the old laws or enacting into law conditions established by practice or by court decisions. Such interpretations are strongly supported by some Federal judges and members of the Patent office. Other Federal judges and the *Journal of the Patent Office Society* seem to take the opposite view and believe this law is new.

Of the new section on Patentability the Senate committee report says "Section 103, for the first time in our statute, provides a condition which exists in the law and has existed more than 100 years, but only by reason of decisions of the courts," but also says "There is no provision corresponding to the first sentence explicitly stated in the present statutes . . . The second sentence states that patentability as to this requirement is not to be negatived by the manner in which the invention was made, that is, it is immaterial whether it resulted from long toil and experimentation or from a flash of genius."

Judge Picard in Gagnier Fibre Products Co. v. Fourslides Inc. (U. S. D. C., E. Mich., June 10, 1953) recently said "This, we must admit, is new, because in a Senate report that clause is clarified and it does change some phases of case law."

Colonel Toulmin, nationally known patent attorney, business leader and author, takes the view of industry as expressed before Congress that many of its provisions are really new. In this thought-provoking article he presents his interpretation of the 1953 law which, he contends, has created a climate much more favorable to manufacturing enterprise.

NOW, engineering and design at last get a fair break under the new Patent laws, which went into effect on January 1, 1953. Prior to that date the United States Courts for twenty-five years have tried to make over engineering and manufacturing to fit European methods and thereby set aside important features of the existing law. So, in the new Patent law Congress went back to the first principles of our Constitutional Convention of 1787 with the result that you can now patent either scientific discoveries or practical useful inventions.

To understand this complete housecleaning of many judicially sacred cows, we must look at a little history. When our Constitution was in the making at Philadelphia in 1787, patenting useful things was a must. For the right to do our own engineering and manufacturing was one of the basic issues on which we were fighting England to free our colonies. So into the Constitution went a provision that patent laws meant protection for two groups of inventors: men who did new and useful things and those who made scientific discoveries.

During the last quarter century our Courts could not see protection except for the most extreme scientific advances—the "useful" inventions were slaughtered by the carload. The Courts also said in effect: "Mr. Designer, you have got to push back the frontiers of science of physics and chemistry, if you want to be an inventor—only a man with a flash of genius can get a valid patent." Inventions that were practical, new and useful from

Section 100. Definitions

When used in this title unless the context otherwise indicates—

- **a. The term "invention" means invention or discovery.**
- **b. The term "process" means process, art or method, and includes a new use of a known process, machine, manufacture, composition of matter, or material.**
- **d. The word "patentee" includes not only the patentee to whom the patent was issued but also the successors in title to the patentee.**

which industry made its millions went into the discard by judicial fiat.

New Standards of Invention: Now this is all changed by Congress—today when you sit down to your board or start experimenting in your shop, Congress says you are an inventor worthy of the nation's protection. Under the new Patent laws you are an inventor if what you do is new and useful, and invention, unless it is "obvious" to a man with "ordinary skill in the art" reviewing the invention "as a whole" that what you have done is not invention, *Sections* 101 and 103.

The highly paid patent expert who testifies for a fee that he could find what you did here and there in prior patents from which he reconstructs your idea is a dead duck. Engineers like you are now going to say what's new, useful and invention—and the Courts must follow your judgment as a man with "ordinary skill in the art." To defeat an invention it must be "obvious" that it is old, looking at it "as a whole" and not piecemeal.

This is a new standard of invention—if you make a new and useful contribution not obviously old to your ordinarily skilled fellow-workers, it is invention. The new law requires us to go back to the Founding Fathers' idea that the Patent law was to protect "useful" ideas as well as the more high-hat scientific discoveries.

Let us see how this works out. The new law provides another startling provision—startling because it is so sensible. You can now patent a *"new use* of a *known process,* machine, manufacture, composition of matter, or material," *Section* 100 *b.* This provision quoted from the new law opens up for repatenting *new uses* of our vast storehouse of our past inventions so they can be put to work all over again at more modern tasks.

Section 101. Inventions patentable

Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title.

Section 103. Conditions for patentability; non-obvious subject matter

A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

Section 271. Infringement of patent

b. Whoever actively induces infringement of a patent shall be liable as an infringer.

c. Whoever sells a component of a patented machine, manufacture, combination or composition, or a material or apparatus for use in practicing a patented process, constituting a material part of the invention, knowing the same to be especially made or especially adapted for use in an infringement of such patent, and not a staple article or commodity of commerce suitable for substantial noninfringing use, shall be liable as a contributory infringer.

Section 118. Filing by other than inventor

Whenever an inventor refuses to execute an application for patent, or cannot be found or reached after diligent effort, a person to whom the inventor has assigned or agreed in writing to assign the invention or who otherwise shows sufficient proprietary interest in the matter justifying such action, may make application for patent on behalf of and as agent for the inventor on proof of the pertinent facts and a showing that such action is necessary to preserve the rights of the parties or to prevent irreparable damage; and the Commissioner may grant a patent to such inventor upon such notice to him as the Commissioner deems sufficient, and on compliance with such regulations as he prescribes.

Contributory Infringement: Behind this lies a dramatic story! Our Courts proceeded during this last twenty-five years to reverse all the old court decisions by holding that you could not protect your business in supplying specially designed parts, which formed a part of your patented combination of parts—that was contributory infringement.

In the United States we seldom find a company making all of the parts of its claimed subject matter in its patents. We are a nation of production specialists. For instance, the profit in a stoker control for a switch company is in the sale of switches. The whole patented combination on stoker controls, including the stoker, with its specifically designed switches, was rarely made in the United States as a unit. Contrary to European practice of making the complete machine even to nuts, bolts and screws, in the United States parts of complete machines are made by different companies.

This new Patent Code reverses the Supreme Court on contributory infringement. This term now means that if you manufacture and sell a part specifically designed to complete another's patent combination—like the special switch for the patented stoker—you are an infringer with all its penalties, *Section* 271.

But until the new law was enacted the Courts held you could not use your patent to protect against contributory infringement; and if you tried to do it, you "misused" your patent under the Antitrust laws and your patent was defeated by the Courts.

Section 116. Joint inventors

If a joint inventor refuses to join in an application for patent or cannot be found or reached after diligent effort, the application may be made by the other inventor on behalf of himself and the omitted inventor. The Commissioner, on proof of the pertinent facts and after such notice to the omitted inventor as he prescribes, may grant a patent to the inventor making the application, subject to the same rights which the omitted inventor would have had if he had been joined. The omitted inventor may subsequently join in the application.

Whenever a person is joined in an application for patent as joint inventor through error, or a joint inventor is not included in an application through error, and such error arose without any deceptive intention on his part, the Commissioner may permit the application to be amended accordingly, under such terms as he prescribes.

Section 256. Misjoinder of inventors

Whenever a patent is issued on the application of persons as joint inventors and it appears that one of such persons was not in fact a joint inventor, and that he was included as a joint inventor by error and without any deceptive intention, the Commissioner may, on application of all the parties and assignees, with proof of the facts and such other requirements as may be imposed, issue a certificate deleting the name of the erroneously joined person from the patent.

Whenever a patent is issued and it appears that a person was a joint inventor, but was omitted by error and without deceptive intention on his part, the Commissioner may, on application of all the parties and assignees, with proof of the facts and such other requirements as may be imposed, issue a certificate adding his name to the patent as a joint inventor.

The misjoinder or nonjoinder of joint inventors shall not invalidate a patent, if such error can be corrected as provided in this section. The court before which such matter is called in question may order correction of the patent on notice and hearing of all parties concerned and the Commissioner shall issue a certificate accordingly.

Now all this is changed. The new law recognizes that we operate in the American way and not the European where one company makes everything from its screws to the complete construction.

If you design parts specifically fitted to your patented combination—design that electric motor or paper feeder to fit your machine only—you can patent it in your particular combination as an integral part. Then the law will protect you in keeping others from making and selling that particular element. Contributory infringement has been restored.

Be careful, too, of the teeth in the new law. Take a good, long look at your competitors' patents before going too far on the drawing board.

Infringement Damages: And here is an essential precaution. The new law says you are an infringer if you "induce" anyone to become an infringer—your company, its engineers and salesmen will be guilty of infringement if they "sell" or help sell anything that contributes to infringement or is infringement, *Section* 271 *b*. Patent liability is much broader now.

Under the old regulation, if you licensed others to make one of the special parts of your combination you stood to lose your whole patent. Now the law says that is legal; and in doing so opens vast areas for profit to the patent owner. The Supreme Court was again reversed by Congress.

Patenting New Uses: Coming back to new uses of old processes, articles of manufacture and products can now be patented, *Section* 100 *b*. The area of patenting has been vastly increased. Be sure when you develop something new, you use your imagination and have your patent attorney list all the possible uses of your idea in your patent to prevent others coming along later and patenting new uses of your inventions.

Engineering and Research: Here is another break for engineering and research—the new law says in effect that it makes no difference whether you, as an inventor do it with "a flash of genius" or by an ordinary plodding. If your idea is new, useful and inventive, you will be protected. It makes no difference now whether you developed your idea in the cellar workshop by yourself or as a part of a team in a multi-million dollar workshop.

Research under the new law is respectable. Modern mass engineering and research so often necessary under modern conditions, is now recognized as vital to American success. Its results are patentable. The decisions of the Courts in the last

Section 121. Divisional applications

A patent issuing on an application with respect to which a requirement for restriction under this section has been made, or on an application filed as a result of such a requirement, shall not be used as a reference either in the Patent Office or in the courts against a divisional application or against the original application or any patent issued on either of them, if the divisional application is filed before the issuance of the patent on the other application. If a divisional application is directed solely to subject matter described and claimed in the original application as filed, the Commissioner may dispense with signing and execution by the inventor. The validity of a patent shall not be questioned for failure of the Commissioner to require the application to be restricted to one invention.

twenty years that practically only the lone inventor could invent is discarded by Congress. The law now says in its quaint way "Patentability shall not be negatived by the manner in which the invention was made," *Section* 103.

Under the old decisions the Courts were hostile to ideas from the best engineering and technical brains of the nation, just because a group of researchers or designers produced the invention. Only a lone individual with a flash of genius could invent under the old law and then only if he pushed back the frontiers of chemistry and physics. Congress is to be thanked for returning the Patent System to American methods of developing new products and processes.

Engineer and Employer: Ownership of inventions and development of inventions have come in for a long overdue overhaul. No longer can a man, who is hired to engineer and design, refuse to assign his new developments to his employer. If he refuses, the employer can file the patent application in his name and sign the papers, *Section* 118. "Hold-outs" from legal contract arrangements are taboo.

All the employer has to do to have the right to sign for a designer who refuses to sign his patent application, is to show by writing or other means a "proprietary" interest in the matter justifying such action; and that the action is necessary to preserve the rights of both parties.

Hence, it now becomes vital to settle such matters by employment contract. Nothing should be left to chance to protect the invention rights of both employer and inventor.

If you are a joint inventor with another, and you refuse to sign with him, he can sign for you, *Section* 116. These rules also apply when an inventor disappears and cannot be found.

Then, too, if you make a mistake as to who is the inventor or inventors, this can be corrected at any time so long as there is no deceptive intent, *Sections* 116 and 256.

Section 186. Penalty

Whoever, during the period or periods of time an invention has been ordered to be kept secret and the grant of a patent thereon withheld pursuant to section 181 of this title, shall, with knowledge of such order and without due authorization, willfully publish or disclose or authorize or cause to be published or disclosed the invention, or material information with respect thereto, or whoever, in violation of the provisions of section 184 of this title, shall file or cause or authorize to be filed in any foreign country an application for patent or for the registration of a utility model, industrial design, or model in respect of any invention made in the United States, shall, upon conviction, be fined not more than $10,000 or imprisoned for not more than two years, or both.

The problem of signing divisional applications has long been a troublesome one. An engineer signs the original application—in a month or year later the Patent Office says there is more than one invention in the application. By now, the engineer has moved away or is unfriendly. Under the new law the signature of the inventor is no longer needed on true divisional applications, *Section* 121.

Again under the old rules, if your application had more than one invention in it, the Patent Office made you file separate patent applications on each separate phase of your invention, even though all the ideas were in a complete machine like a machine tool. The tragic result was that, if any one of these divisional applications issued ahead of the other, the Patent Office turned on you and rejected all your pending applications on the one first to issue. You were penalized because one Patent Office Division worked faster than the other.

The new law now says this tough policy by the Patent Office is out, *Section* 121.

Atomic Age and the Patent Law: Our National Defense policies have put teeth in the new patent law during this age of insecurity, war and top secrets, *Section* 186. You must wait six months after filing your application in the United States Patent Office before filing abroad. Additionally, you must get a license to export your new ideas before filing patent applications abroad. To ignore these rules is to risk losing your patent rights in the United States. Then, too, a government department may decide your idea is too new and too "hot" to publish—so it will be held in the Patent Office under orders of secrecy, but there are provisions made to compensate the inventor or his company.

Conclusion: So you see the fields of invention in which you can patent have been greatly expanded. The practical, useful ideas of America that are new and invention can again be protected—the section of our Constitution on "useful" inventions is restored. Technicalities have been eliminated in the Courts and Patent Office—procedures can be streamlined.

Dangers of infringement are greatly increased. The opportunities for profit from manufacturing parts of patented combinations and licensing have been increased.

To the America of mass manufacturing and mass selling has been added mass inventing. Great engineering team developments, vast research teamwork and specialty manufacturing of patented parts by separate companies is at last recognized. Give Congress a hand for helping build a greater America and reversing the negative decisions of the Courts of the last quarter century!

The official title of the new patent law is "35 U. S. C. (1952) Public Law 593, 82nd Congress, 2nd session, c. 950, 66 Stat. 792." New Patent Office Rules of January 1, 1953 have also been issued in connection with the new patent law. The New Rules are for sale by the Superintendent of Documents, U. S. Government Printing Office. Copies of the statute can be obtained from that office (Federal Register) or from the Bureau of National Affairs, 1231 24th Street N. W., Washington 7.

Magnetic Tape Drive . . . designed for minimum speed variation

By Edward S. Kinney

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Redwood City, Calif.

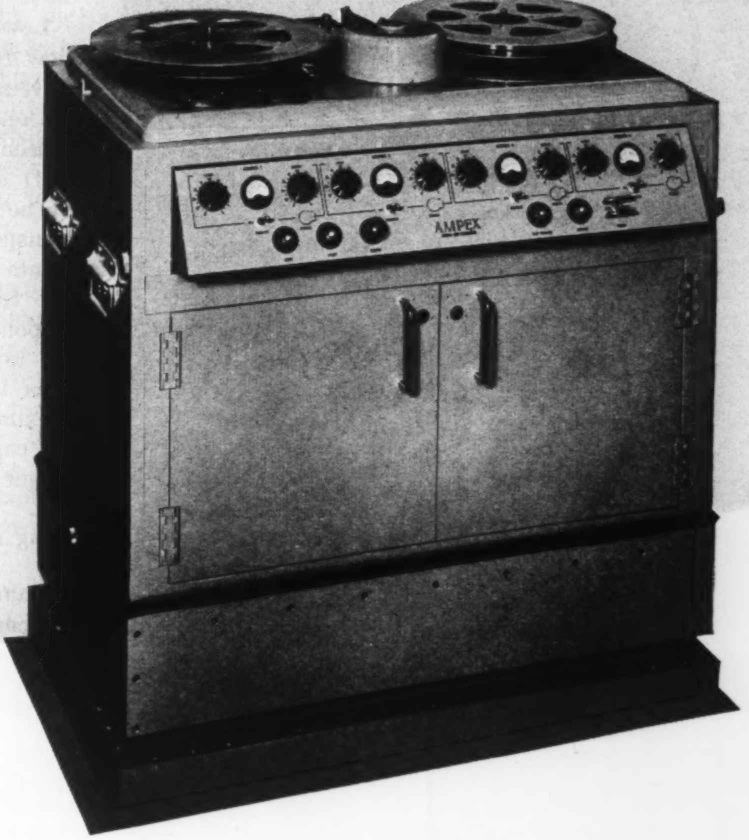

Fig. 1—Tape recorders such as this used in instrumentation applications have tape transport systems with speed variation of 0.04 per cent or less

CONSTANT-SPEED transport of strip material is important in a variety of applications such as strip mills and paper making machinery. Important as it is in these applications, constant-speed transport is even more important in tape recorders used for industrial or instrumentation applications such as telemetering, *Fig.* 1.

Although the conventional tape transport arrangement, *Fig.* 2, provides sufficiently constant-speed tape motion to satisfy the demands of critical listeners in the reproduction of music or other audible sound, for recording of critical data it may introduce errors of 2.5 to 5 per cent which cannot be tolerated. Such instrumentation applications demand that speed regulation be reduced by a factor of ten.

Conventional Drive: Flutter, which is defined as any real or effective change in linear velocity, may be introduced in conventional magnetic recording tape transport systems in any of the following ways:

1. Irregular angular velocity of the constant-speed driving capstan caused by bearing irregularity, eccentricity of the driving surface, etc.
2. Tape may not be paid out of the supply reel smoothly.
3. Tape may scrape across the heads and thus sus-

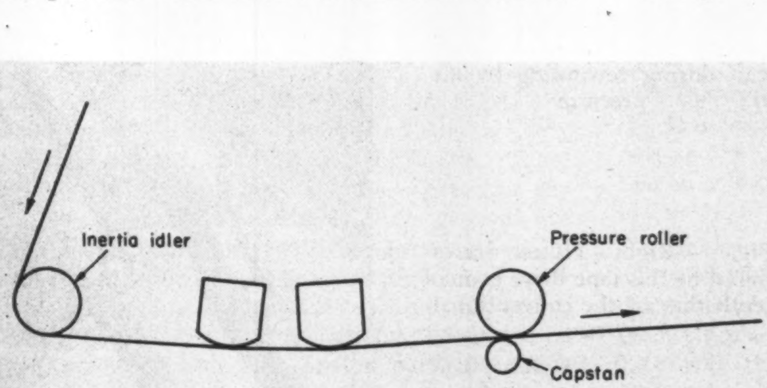

Fig. 2—Design of conventional magnetic tape drive introduces excessive errors in data recording

tain vibrations along its longitudinal axis.

4. Inertia idler between the supply reel and the head may have uneven angular velocity due to bearing irregularity or eccentricity.
5. Uneven take-up tension reflecting back through the constant-speed drive to the region of the heads.

Low-frequency flutter or wow may be introduced by slow frequency changes in the supply voltage to the drive motor, by deformation of the tape due to humidity and temperature, or by stretching of the tape caused by tension applied either as hold back (supply reel) or take-up.

The most serious source of flutter in the conventional transport is due to the variation in friction at the points where the tape contacts the heads. This gives rise to undesirable amounts of flutter at a rate corresponding to the resonant frequency of the system of the tape stretched across the heads between the inertia idler and the capstan. With a spacing of approximately 6 inches between the inertia idler and the capstan and with ¼-inch wide tape, the resonant frequency falls between 1500 and 3500 cycles per second. This results in higher than usable noise when using a wide-band FM system.

Improved Drive: With the conventional transport system as a starting point, several improvements in design can be realized. The first approach for improved tape motion might be one used by the motion picture industry for many years. This system, known as the closed-loop drive, *Fig.* 3, consists of a constant-speed capstan with idler which holds the tape in intimate contact with the driving surface. The tape, after passing the capstan, contacts the record head, passes around the mechanical filter (inertia idler) contacts the play-back head and again is locked to the capstan by an idler. This transport system reduces the effect of variations in tension of supply and take-up mechanisms. Since the unsupported length of tape is appreciably reduced, the problem of high-frequency flutter is correspondingly lessened. The resonant frequency of the system is higher and, therefore, the displacement of the tape reduced.

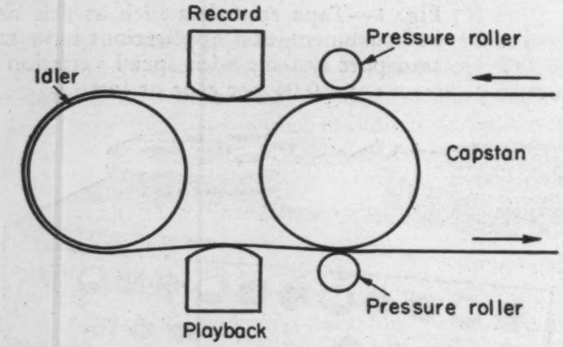

Fig. 3—Closed loop magnetic tape drive is better than the conventional system

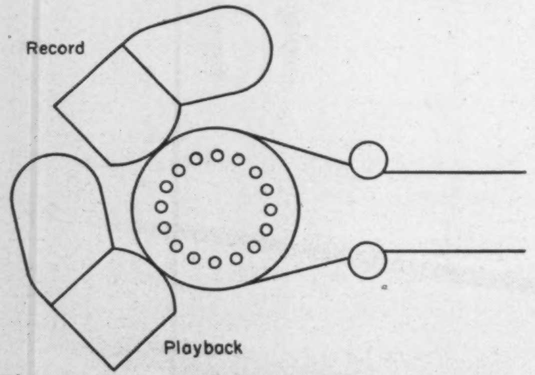

Fig. 4—Basic configuration of tape drive designed to produce minimum flutter by reduction of unsupported length of tape

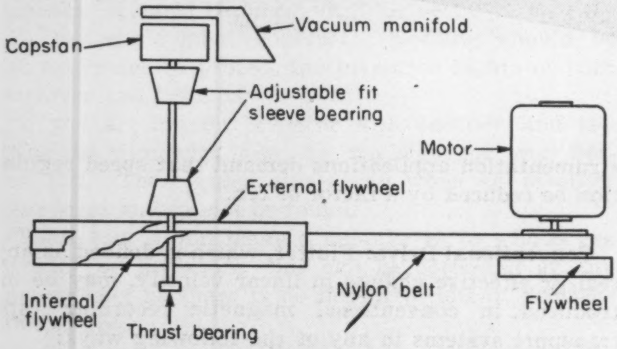

Fig. 5—Drive mechanism of low-flutter recorder. Adjustable sleeve bearings eliminate shaft wobble

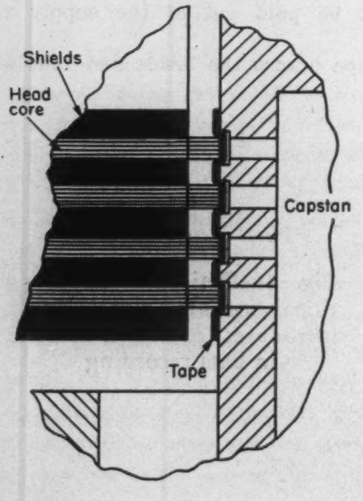

Fig. 6—Left—Tape is held to capstan by vacuum during recording and away from capstan during rewinding by air pressure

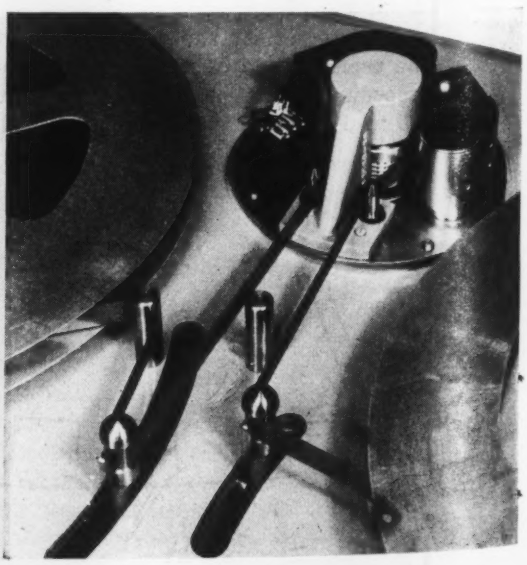

Fig. 7—Right—Flutter introduced by this tape drive is one-tenth that of the conventional system

The closed-loop drive is, however, susceptible to variations in friction at all the idlers and this affects the capstan speed unless it is of exceptionally low mechanical impedance. Tape slippage and variations in friction, as the tape passes the heads, remain as undesirable features in this type of drive. A desirable improvement could be realized by reducing the length of unsupported tape to as near zero as practical and thereby reduce the sliding friction type of flutter. If the idlers could be eliminated, further sources of flutter would be removed. It would also be desirable to eliminate the inertia idler, as bearing trouble can develop or an eccentric condition may exist which would introduce speed irregularities.

Final Design: The design chosen to best achieve the desirable features discussed in the foregoing is shown in *Fig.* 4. Used in this design are: a capstan, loop of tape around the capstan "steered" in and out by the vertical guides, and record and playback heads with means to allow the heads to contact the tape which is in turn contacting the capstan. This system, which reduces the unsupported length of tape to a practical minimum, is used in the recorder shown in *Fig.* 1.

Air pressure is used to hold the tape in intimate contact with the capstan, thus holding slippage to a minimum and eliminating idlers. By having the holes in the top of the capstan connect to corresponding portions of the driving surface of the capstan drum and evacuating the portion of the capstan covered by the tape, the tape is firmly held to the surface of the capstan.

The drive mechanism used in achieving this low-flutter system is shown in *Fig.* 5. At the top is the capstan around which the tape travels and the vacuum manifold which connects the vacuum pump to the capstan. The capstan is fitted to a precision shaft and supported in adjustable sleeve bearings which provide the close tolerance fits necessary to prevent any unwanted wobble of the capstan shaft. A large flywheel is mounted on this shaft and the assembly supported on a ball thrust bearing. This thrust bearing must have very low torque variation with respect to the energy stored in the flywheel. Inside the large flywheel is a second flywheel separated by a 1/32-inch film of silicone fluid. The inner flywheel stores most of the energy but is coupled to the capstan only by the film of oil.

At the high tape speeds used, any variation in the thickness of the tape would cause a severe pounding action from the heads as the pressure increased for an instant then dropped off to near zero. Therefore, a compliant contact is provided between the heads and the tape, and the tape is unsupported for the very small portion between the sides of the grooves. There are four grooves, *Fig.* 6, around the capstan at the point of head contact. In each of these grooves are numerous holes connecting with the sectionalized interior of the capstan. These sections are in turn evacuated behind the tape by connection with the selecting manifold. The tape is represented by the dark line between the heads and the capstan surface. Since abnormal wear might be incurred during periods of rewinding and fast forwarding of the tape, the vacuum system is reversed during these modes of operation, holding the tape away from the capstan.

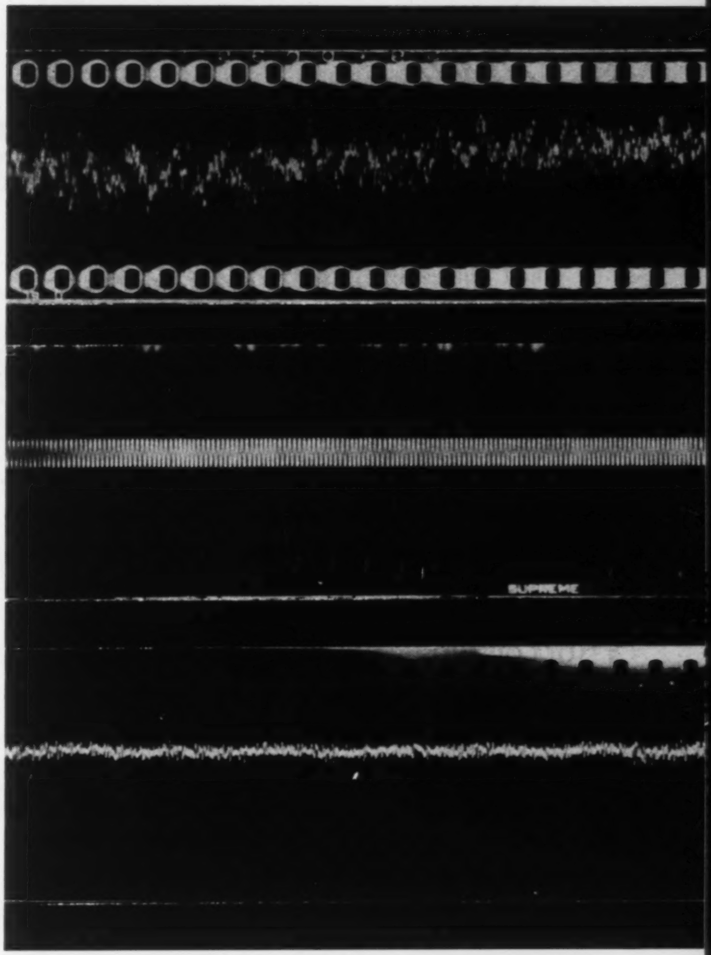

Fig. 8—Center trace is a calibrating signal representing peak-to-peak deviation of 0.1 per cent. Upper trace is flutter introduced by the conventional drive which has a peak-to-peak deviation in excess of 0.4 per cent. Lower trace shows flutter of redesigned drive to be 0.04 per cent of peak-to-peak

The supply reel, right side, *Fig.* 7, turns in a clockwise direction, paying out tape past the constant-tension brake, past the guide and onto the capstan. The constant-tension brake is a portion of the mechanical feedback system whereby the tension of the tape entering the capstan is maintained constant. The tape exits from the capstan past a vertical positioning guide, around the tension arm and guide pin, and onto the take-up reel. This left tension arm takes up the loop in fast starting and shuts down the transport in the event of tape breakage. A damping system on this arm is provided to prevent excessive strain in the tape during the fast start operation.

A comparison, *Fig.* 8, between the measured flutter in the conventional transport system and in the new design drive shows that the new design reduces flutter from 0.4 per cent peak-to-peak value to 0.04 per cent, satisfying the original requirement of a 10 to 1 reduction.

DESIGNING SPRINGS

How to achieve simplification and reduce costs

Part 2—Extension Springs

By Stanley L. Albright

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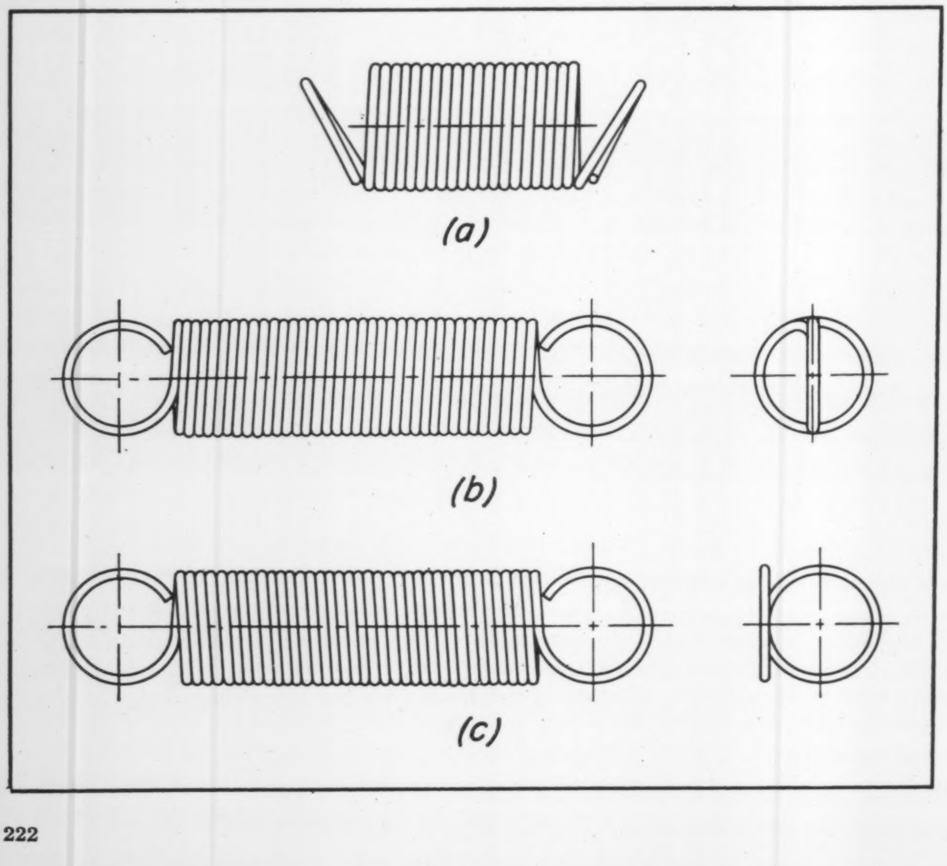
FOLLOWING the pattern established in Part 1 of this series, Compression Springs, this article treats extension springs with particular emphasis on the cost factors involved in end design. In the final article to follow, the important considerations influencing the design of torsion springs will be discussed.

Special coiling-machine attachments and custom-made forming dies make it possible to produce an infinite variety of special spring ends. Because the only function of a spring end is to secure the spring in a machine, the required shape, length and strength of the end depend only on machine requirements. The additional cost of special spring ends is justified only in applications where precision operation or special attachment is necessary. However, spring cost is frequently unnecessarily high because special ends are requested (out of habit more than anything else) for installation where a less expensive spring is satisfactory.

Methods of Attachment



The angle hook on the extension spring at *a* is both the simplest and least expensive of all spring hooks or ends, with the exception of a few open coils on either end of the spring. This hook shape requires neither additional manufacturing operations nor special attachments on the spring coiler and, as compared to the common twisted loop, *b*, or full loop-at-side, *c*, actually eliminates one operation at each end. A basic spring form, the angle hook provides satisfactory service in many applications where a precision spring is not required. Because of coiling machine limitations, however, it is not practical to form the angle hook on springs with over ten coils.

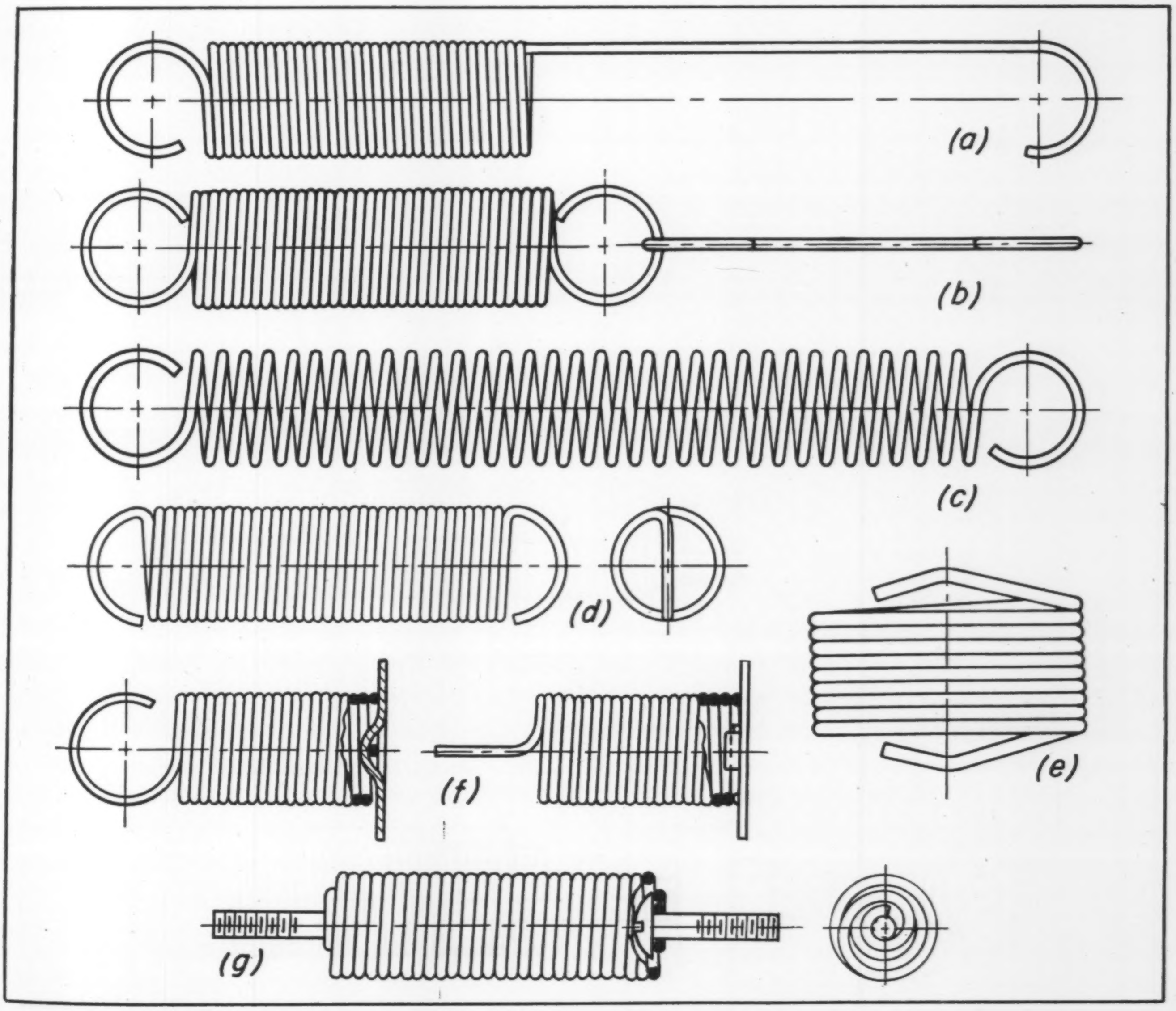
Adjustment of Length

Often the designer finds that a spring with proper load characteristics is too short to fit properly between available points of attachment. Some way must then be devised for lengthening the distance between hooks with minimum increase in cost and no effect on load-at-length.

This problem is simply solved with an extended hook at one end providing the required increase in hook separation, *a*. The other end has a simple twisted loop. Of course, the extended hook is more expensive than either the angle hook or the twisted loop because additional forming operations are required after the spring is coiled. Manufacturing difficulties, particularly where the increase in hook separation must be large, may make it less expensive to use the extension spring with standard hooks combined with a special wire form, *b*. The same load characteristics may also be achieved with an open-wound extension spring, *c*.

Conversely, the designer may find that his spring is too long for the space available. If the space cannot be increased, the end arrangements of design *d* may be used to eliminate some or all of the total hook length. Lengths of most standard spring ends are equal to the ID of the spring; use of the machine half loop at *d*, with a length of only one-half the ID of the spring, cuts the total hook length in half. Where still more space must be saved, special die-formed hooks, *e*, may be specified.

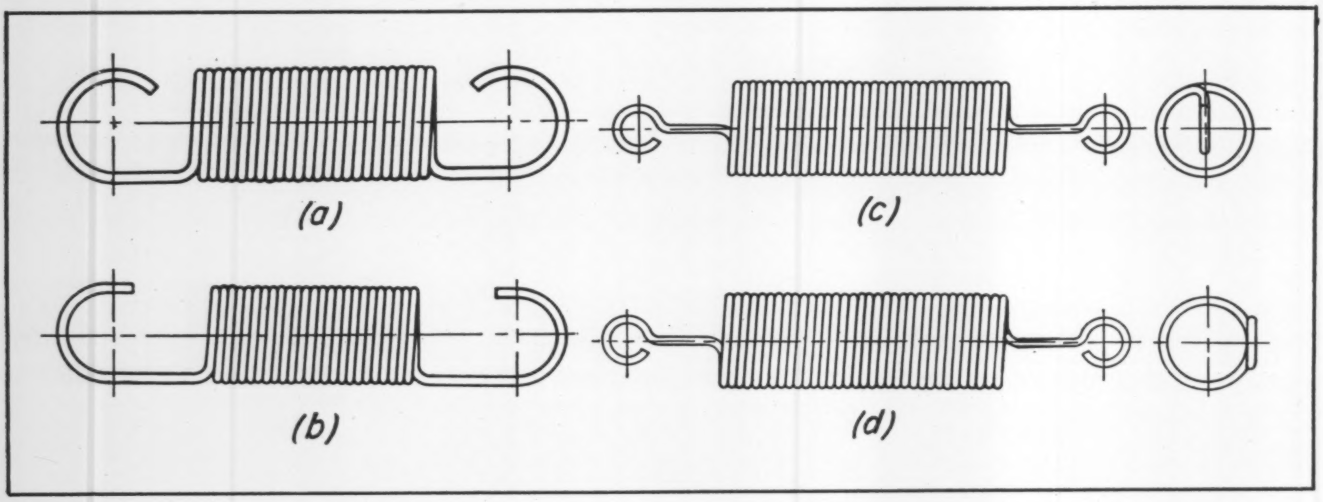
In design *f*, total length of the spring has been reduced one coil diameter by replacing a hook with an insert method of attachment. The spring end lies on a diameter in the plane of the last coil and is simply inserted into a special stamped piece. Although the spring itself is no more expensive, there probably will be additional cost involved in the stamping. In design *g*, the ends of a spring have been automatically spiralled down in the planes of the end coils and threaded bolts have been slipped through the spirals. Of course, it is evident that the spring must be flimsy enough (index large enough) so that the ends can be lifted to insert the bolts. On the other hand, if the spring index is too large, the spiral may not be able to contain the bolt heads properly.



Simplification of Extensions

There is little physical difference between the full loop extended to center, *a*, and the extended hook, *b*. Ends of the extended hook are straight (cannot be less than three times the wire diameter) and thus require a straightening operation. Except where a straight end is required by application, the less expensive full loop extended to center should be the one which is specified.

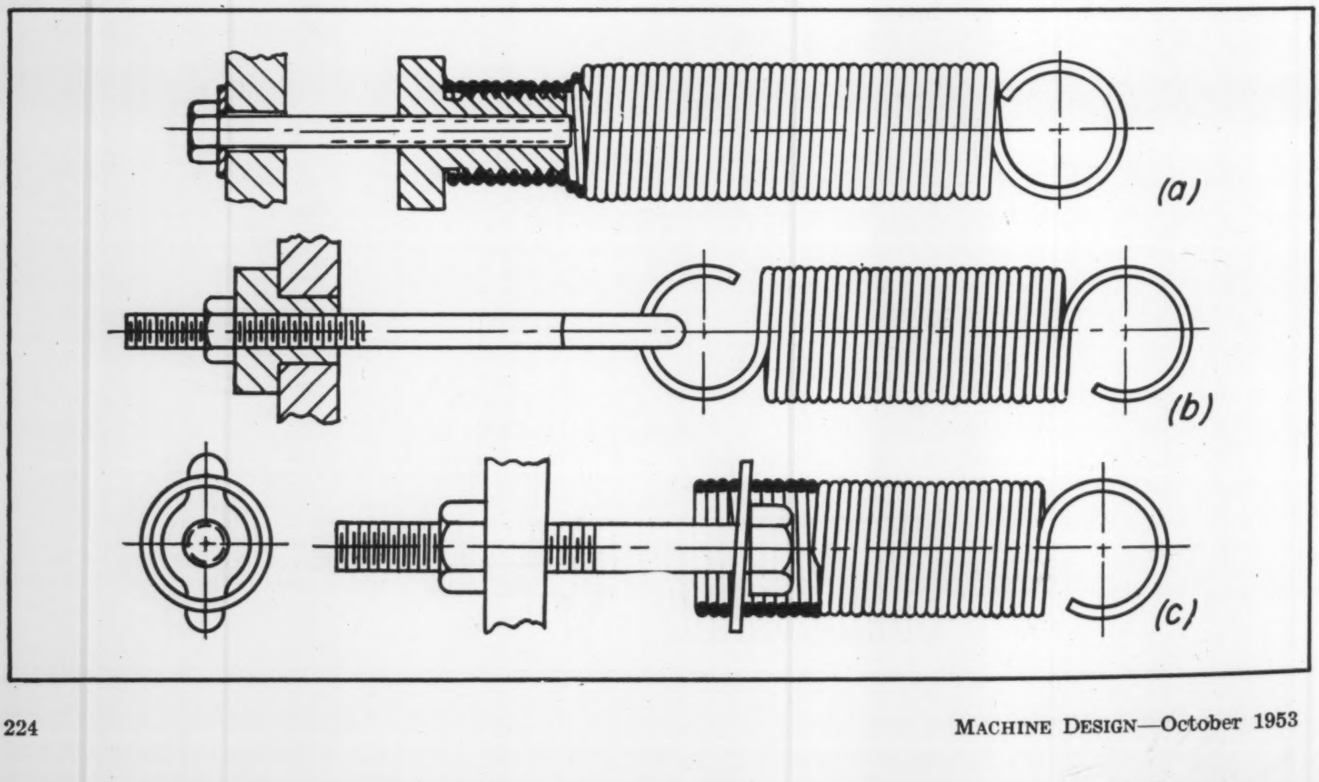
The hook extended from center, *c*, is the most expensive of all hook types. Wire is bent to the center and extended along the axis and the hook is then formed. The hook extended from side, *d*, can be formed in fewer operations and is therefore less expensive.



Adjustment for Load

Two methods for changing load and gradient through a given operating range after installation are shown at *a* and *b*. In design *a* the bolt may be turned in and out of the threaded plug to adjust load. In design *b*, a spring with a standard twisted loop on both ends is used in combination with a threaded hook and nut. The spring length at a given load is changed simply by adjusting the nut which may be conveniently located outside the assembly. This method is slightly less expensive than that at *a*.

A threaded bolt, a nut and a small stamping are used in the assembly at *c* to change both spring length and gradient. While the nut is adjusted to change load, the stamping is turned between coils to vary the number of active coils and therefore the gradient (commonly used in postal scales).

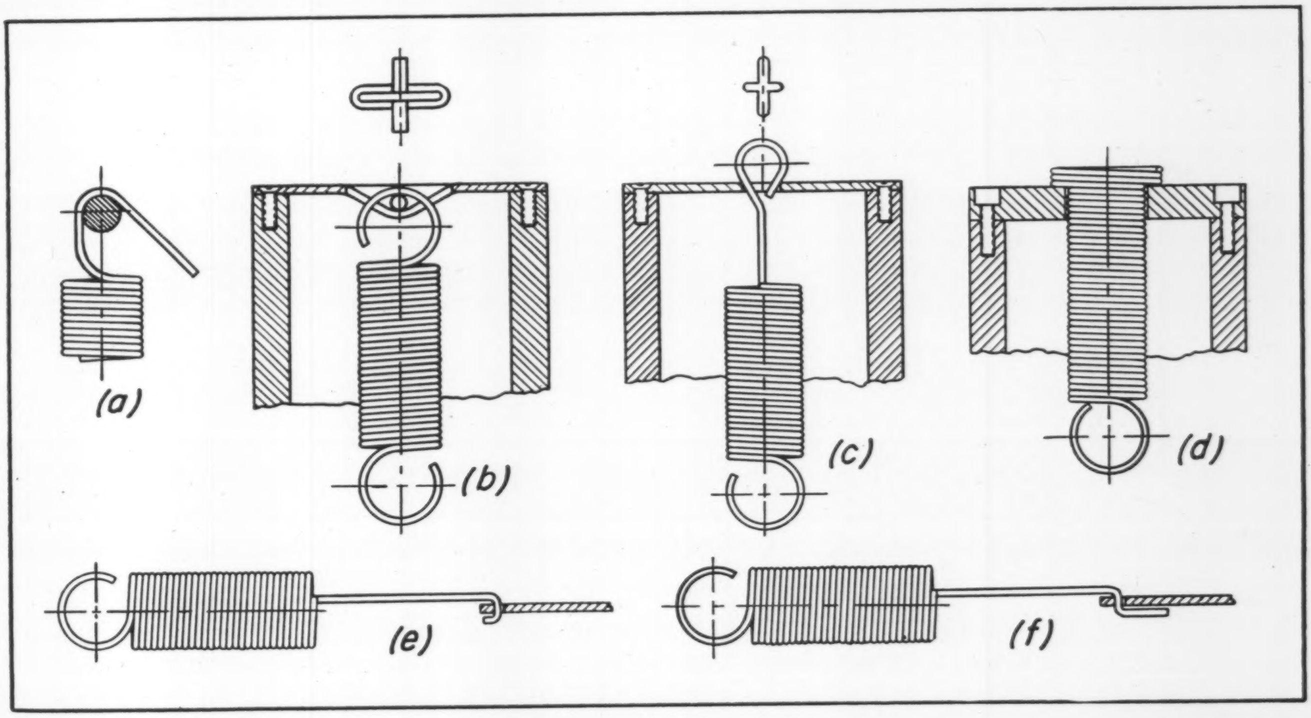


Methods of Assembly

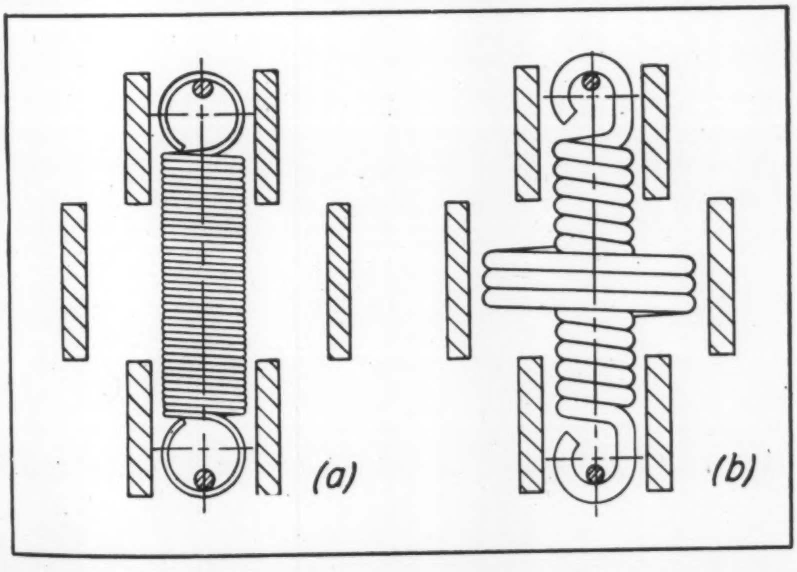
Special hooks or methods of attaching ends are frequently justified by reduced assembly cost. Since springs are usually a comparatively low-cost component in a mechanical assembly, it may be more economical to redesign the spring rather than the mechanism to facilitate assembly. Thus, the installation of springs in locations which are difficult to reach and see may be greatly simplified by a minor change in hook design. For example, the straight hook, *a*, is commonly used where a spring must be placed in position in a blind spot.

Three methods for attaching an extension spring to a metal plate are shown at *b*, *c* and *d*. Design *b* is particularly useful where the spring must be inserted from the inside although the outside alone is visible to the operator. A spring with standard hooks is inserted into a stamped slot and restrained with a pin. In design *c* the same result is obtained without a pin by using a special spring end and a "plus" shaped hole. The spring is passed through the plate in the long slot and turned 90 degrees to seat in the short slot. For both *b* and *c* the spring is installed from the inside. In design *d*, however, the spring is dropped from the outside into an ordinary cylindrical hole. The last few coils have been enlarged on the coiling machine to provide a stop.

A common method of attaching a spring to a plate is shown at *e* and an improved method at *f*.



Utilization of Space

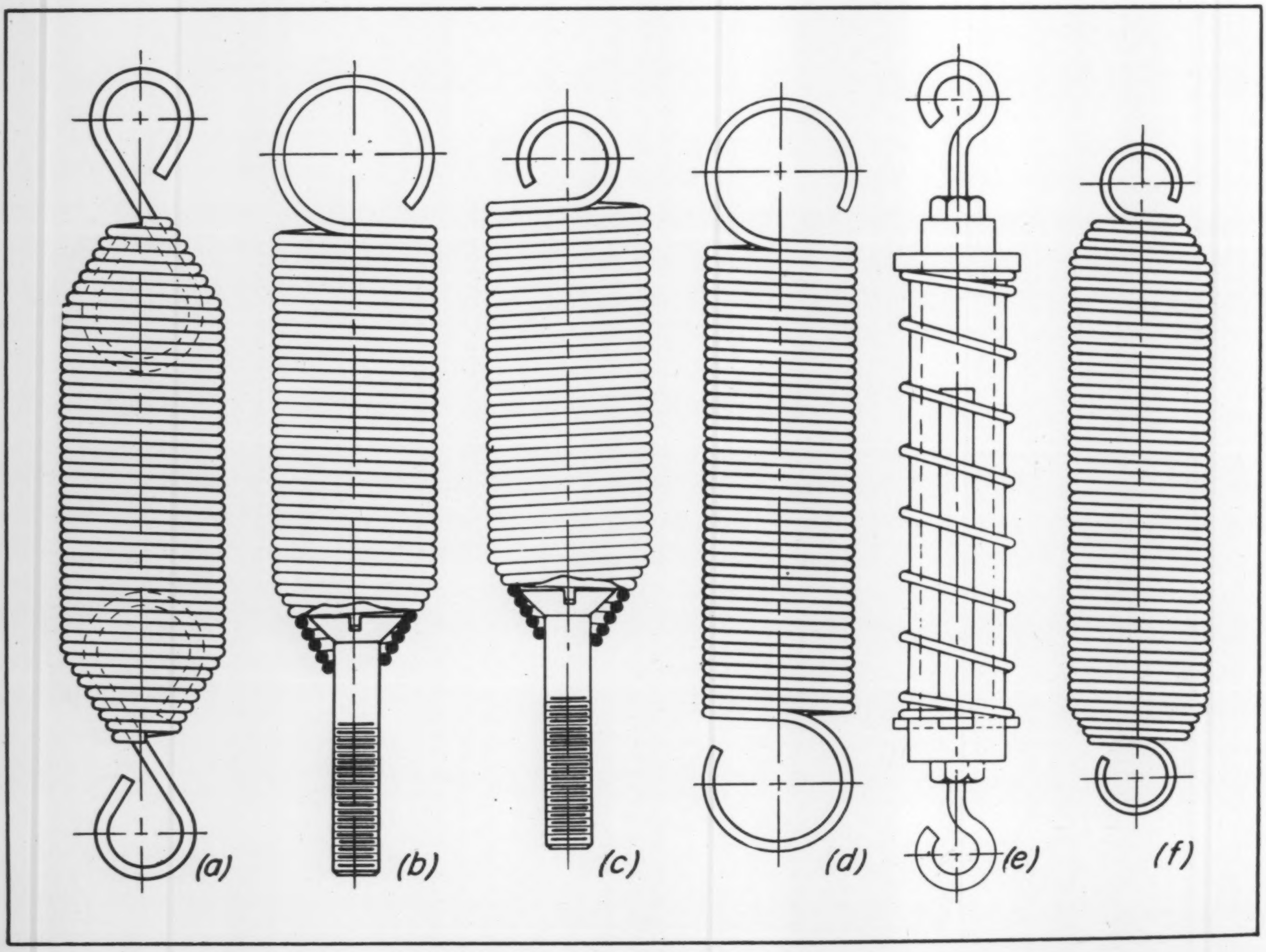


Irregular limiting space conditions can often be used to advantage. At *a*, a conventional extension spring with a comparatively small wire diameter provides the required force in the space available. Because the cavity near the ends of the spring was accepted as the limiting spring diameter, the spring was overstressed and failed in operation. In the design at *b*, the odd-shaped cavity was used to full advantage, permitting a larger wire diameter and eliminating failure. The middle three coils were simply enlarged automatically on the coiling machine to fill the larger cavity diameter at the center with no increase in the cost of coiling.

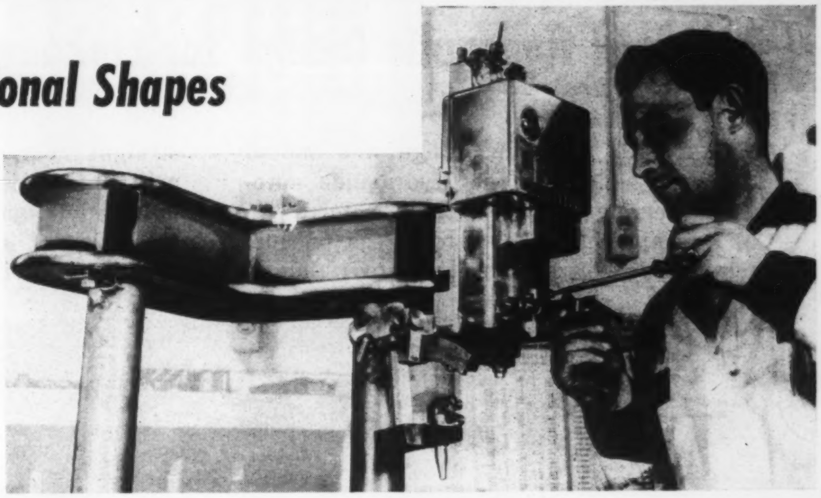
A common cause of spring failure, hook breakage often requires the development of special extension spring ends. As shown at *a*, separately formed hooks may be used by coning the spring ends down over the hooks. Thus, hooks of a larger wire diameter—and greater strength—than the wire in the spring body can be used. However, before resorting to the additional coning operation required, the possibility of designing a conventional extension spring with a larger wire diameter should be investigated.

Hook breakage is usually the result of a surge in operation and may only occur on one end of the spring; the other end may be stationary and able to withstand the shock. Thus, it is necessary only to redesign the spring end where breakage occurs. The spring at *b* has been coiled automatically with a twisted loop on one end and an 8-coil cone on the other. Because the machine screw can be dropped through the looped end after coiling, it is not necessary to cone around the screw head after coiling. With the twisted-loop end stationary, no further breakage is likely to occur. Premature hook breakage, of course, cannot be tolerated and the additional cost of the screw is justified. In the design at *c*, the twisted loop on the other end of the same spring has been reduced to decrease loop stresses. Therefore, the stationary (twisted-loop) end of the spring is also able to withstand higher surge loads.

The evolution of an extension spring design through stages *d*, *e* and *f* represents an actual case in which the manufacturer selected a spring, *d*, experienced excessive hook breakage, replaced the simple extension spring with an extremely expensive compression-extension design, *e*, experienced fracture of the wire, and finally obtained a satisfactory spring of simple design, *f*. Design *d* was selected without considering the operating stresses and was initially found to be acceptable. Because the load was comparatively high and the spring index large, premature hook breakage was later observed. The manufacturer then designed the complicated and very expensive spring arrangement at *e* in which a compression spring is used in combination with an assortment of screw-machine parts. Although the hooks were satisfactory, the compression spring itself failed. The final design, *f*, was based on application requirements and subsequently found to operate without failure. Hook diameter was simply reduced to decrease loop stresses after coning down the spring ends on the coiling machine. Although this spring required a special attachment on the coiler, it was much less expensive than the design at *e*, even if it had worked.



Flame Cutter Scarfs Three-Dimensional Shapes

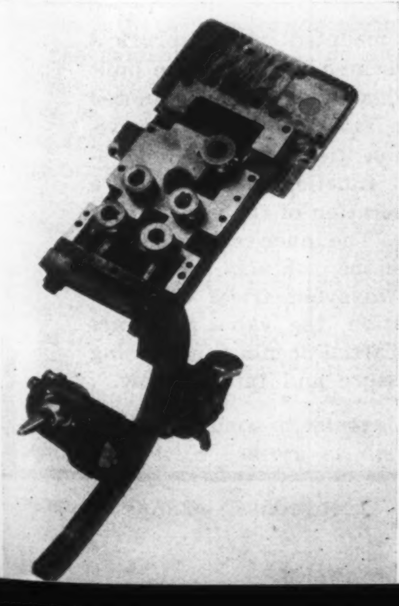


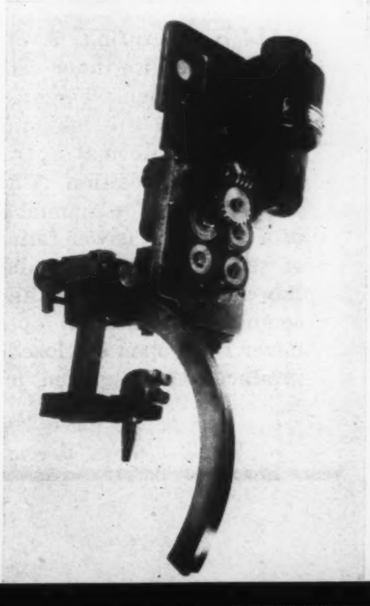
FLAME cutting of metal structures in three dimensions is possible with newly designed flame cutting equipment developed by Milwaukee Shipbuilding Corp. Self-powered and riding on a set of twin rails, the unit cuts curved flat shapes and can also be tilted by the rails to turn the flame from vertical through horizontal to a 22-degree angle above the horizontal for "3-D" pieces. Curved metal pieces or welded subassemblies in thicknesses from ¼ to 8 inches can be scarfed at a constant angle to the plane of the metal with tolerances of 1/32-inch.

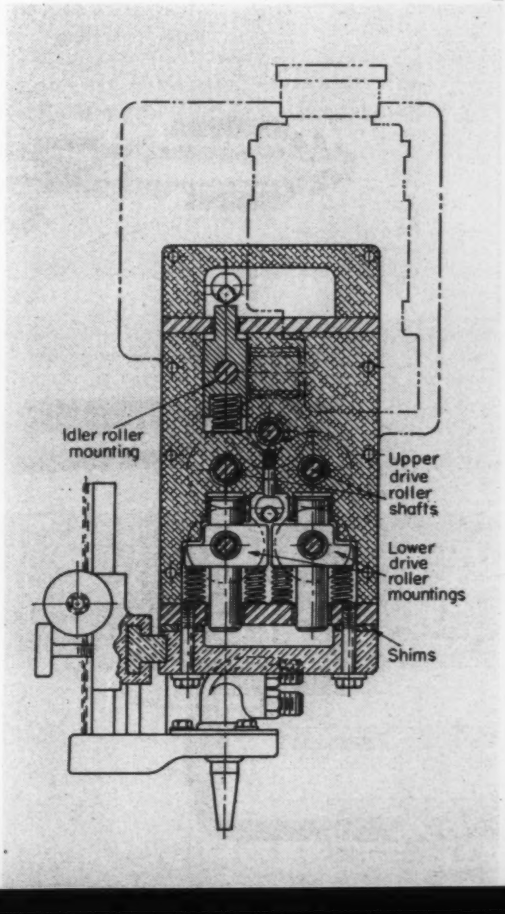
FOUR drive rollers grip the lower guide rail, all power-driven. A fifth idler roller rides the upper rail to stabilize the unit and turn it from a vertical to horizontal plane. One of the four drive rollers is serrated for positive drive, while the other three are smooth and concave to provide differential slippage on curves. The two lower drive rollers, and the idler roller, are spring-loaded.

ALL of the four drive rollers are powered by a small 1/25-horsepower variable-speed ac motor to provide speeds up to 15 inches a minute. Proper gear-tooth clearance in spite of spring pressure is maintained by a set of pitch-diameter rings shrunk onto the gears. Also shown is the sector for varying the scarfing angle of the torch. Aluminum-bronze alloy sectors are furnished in the arc length desired; the torch can be set at any scarfing angle by means of two thumb screws. A hand knob and brass rack permit positioning of the torch to accommodate various material thicknesses as well as positioning of the preheat flames.

SPRING pressure is maintained on the two lower drive rollers and the idler roller when the unit is in operation, pressure being released by turning a set of eccentric cams. Also of importance is the method of compensating for kerf width. A set of shims on the top (shown) and sides (not shown) of the mounting bracket for the torch assembly permits the flame to be shifted by repositioning the whole torch assembly. Once this setting is made for a particular job, it need not be changed.



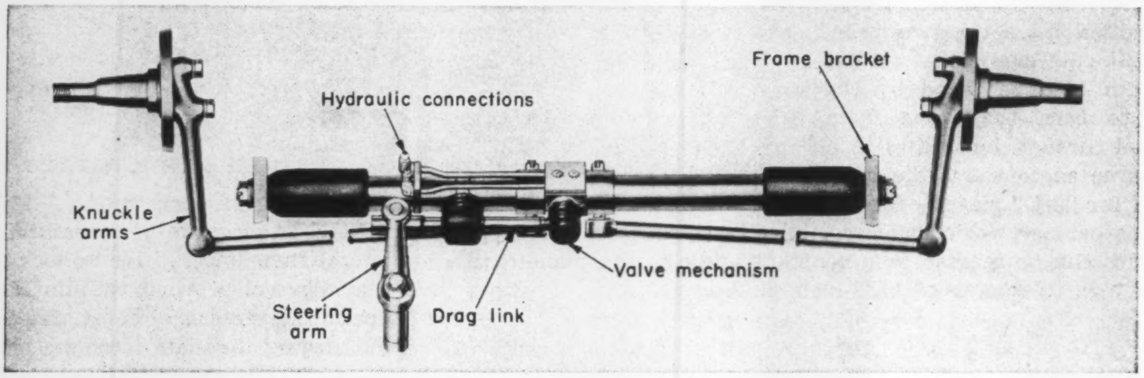




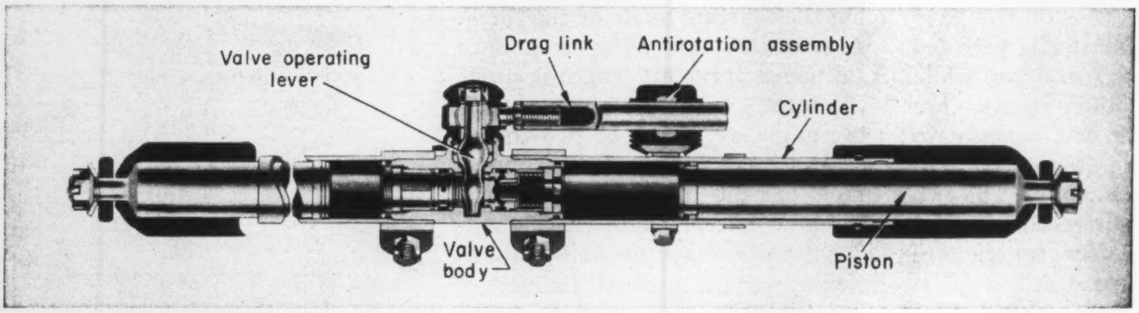
CONTEMPORARY DESIGN

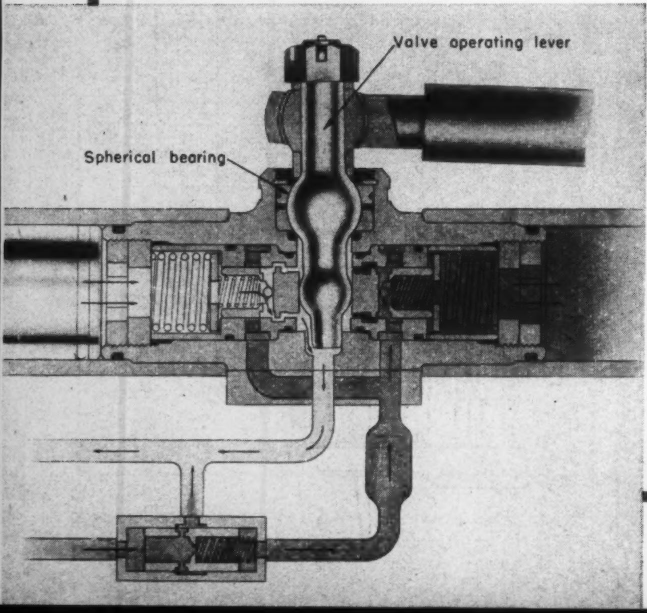
Balanced Hydraulic Design for Linkage Steering Booster

BALANCED hydraulic design was one of the objectives in the Hydraguide automotive steering linkage unit of Gemmer Mfg. Co. By employing equal piston areas, unequal back-pressure forces are eliminated; thus, a straight course is maintained without the artificial "crown" in the road caused by unbalanced design. Additionally, the valve mechanism is not subjected to forces other than those used for actuation.


Frame bracket
Hydraulic connections
Knuckle arms
Valve mechanism
Steering arm
Drag link

TWO CYLINDERS and the valve form one unit, free to move with drag link and steering linkage. Each piston is resiliently mounted on the car frame. The drag link is the operating connection between the valve mechanism and the steering arm. It passes through a bushing with spherical outside surface that fits a split cylindrically bored member rigidly attached to the cylinder assembly to prevent rotation of the whole unit. Thus, if the connection between the steering arm and drag link is correctly placed, movement of the drag link is restricted to the plane formed by the centerline of the cylinders and the valve operating lever. Boots protect the antirotation assembly and the valve operating lever.


Valve operating lever
Drag link
Antirotation assembly
Cylinder
Valve body
Piston


Valve operating lever
Spherical bearing

VALVE operating lever, mounted in a spherical bearing, has its inner end located in a recess to limit its angular displacement. This displacement is limited to less than the maximum movement of the valve, although in normal operation the lever does not approach this position. Chief function is to provide a positive stop for manual operation of the unit in case of a hydraulic power failure. The inner central section of the lever, spherical in shape, contacts and moves the valve pistons in the two symmetrical valve assemblies. In normal operation, the valve ports are never fully open or closed; partial opening and closing produces the required pressure and rate of flow.

STATIC BALANCING

. . . of runners simplified by equations and charts for three methods

By S. R. Uniechowski
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University of Detroit
Detroit, Mich.

IN GENERAL, runners (rotors, impellers, etc.) of hydraulic or steam turbines and large centrifugal pumps are statically balanced by one of the following methods:

1. Machining a cylindrical cut-off from the band with the runner fitted with a certain eccentricity in relation to the axis of the lathe.
2. Machining the crown with tool leaving at the center line of the runner. This is accomplished by locating the axis of the runner at a certain angle to the axis of the lathe. A step, sometimes undesirable, is produced on the finished surface.
3. Machining the crown with a conical cut-off, accomplished also by locating the axis of the runner at a certain angle to the axis of the lathe. However, the section of the material removed is triangular and the inner trace after machining is semielliptical in shape.

Necessary formulas relating dimensions of the cut to the unbalance correction have been generally available for only the first method. This article will outline the procedures and formulas for all three methods.

Cylindrical Cut: In this method the runner is fitted to the lathe with a certain eccentricity, h, or the axis of the runner is shifted the distance h with respect to the axis of the lathe, remaining parallel to it. For h to be as small as possible, the diameter of machining from an eccentric center equals the diameter of the runner before balancing. As depicted in *Fig.* 1, for a small value of h, the shaded area is nearly equal to $2rh$ which is the area of the rectangle $ABCD$. The volume of material, V, removed is equal to $2rhw$ where w is the width of the band cut. It follows that the weight of material removed is $W = V\gamma$ where γ is the material's specific weight.

The moment of material removed and hence the equivalent unbalance, U, is obtained by first determining the difference of moments of areas of the two semicircles with centers at distance h apart. This result is multiplied by the width of the band, w, and the specific weight of the metal γ or

$$U = \frac{\pi r^2 w \gamma}{2}\left[\left(\frac{4r}{3\pi} + h\right) - \frac{4r}{3\pi}\right]$$

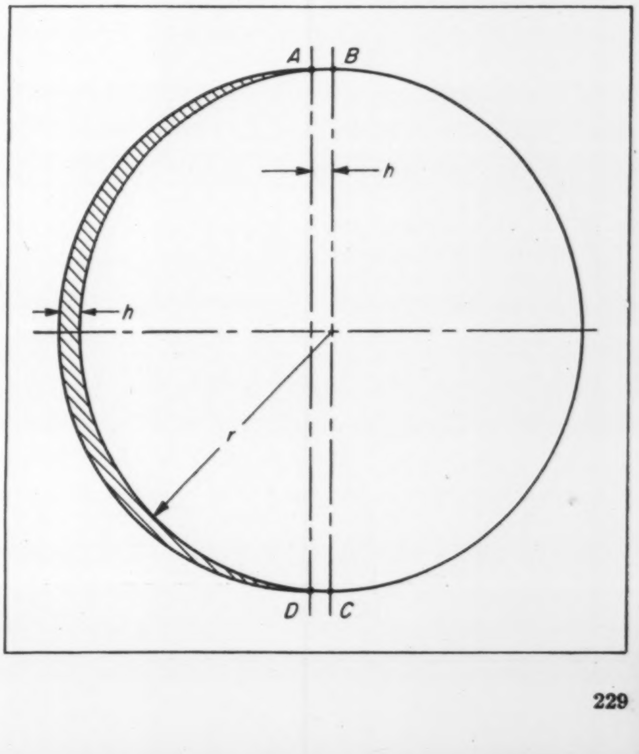
$$= \frac{\pi r^2 w h \gamma}{2}$$

By rearrangement of this equation, eccentricity is

$$h = \frac{2U}{\pi r^2 w \gamma}$$

Step Cut: In this balancing method the tool makes a 180-degree cut with the axis of the runner positioned

Fig. 1 — Cross-section showing cylindrical-cut method of balancing runners



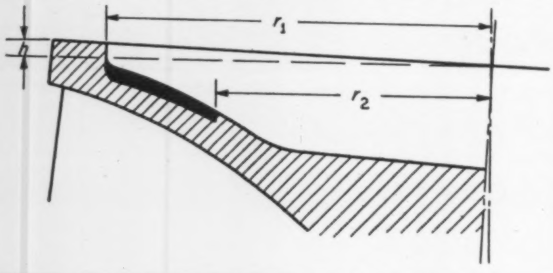


Fig. 2 — Above— Step-cut method of machining runner crown for balancing

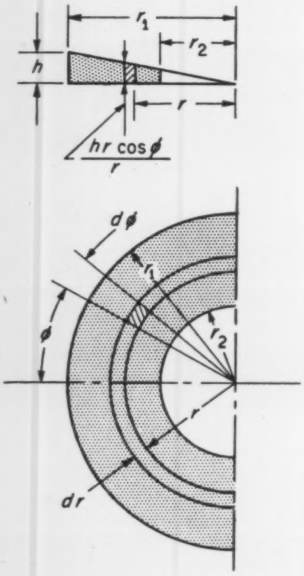


Fig. 3 — Left — Cross-section and plan view of step cut of assumed simplified geometry

at a certain angle to the axis of the lathe. For minimum angle, the machining proceeds to radius r_1 of the runner and is terminated at the runner center line as shown in *Fig.* 2.

The radial offset h of the crown at radius r_1 is calculated by observing in *Fig.* 3 that an element of volume is

$$dV = \frac{h}{r_1}(r\cos\phi)(r\,dr\,d\phi)$$

The total volume is

$$V = \frac{2h}{r_1}\int_{r_2}^{r_1}\int_0^{\pi/2} r^2\cos\phi\,dr\,d\phi$$

$$= \frac{2h}{3r_1}(r_1^3 - r_2^3)$$

with the weight of the material removed understood to be $W = V\gamma$

The moment of material removed which equals the unbalance is

$$U = \frac{2h\gamma}{r_1}\int_{r_2}^{r_1}\int_0^{\pi/2} r^3\cos^2\phi\,dr\,d\phi$$

$$= \frac{\pi h\gamma}{8r_1}(r_1^4 - r_2^4)$$

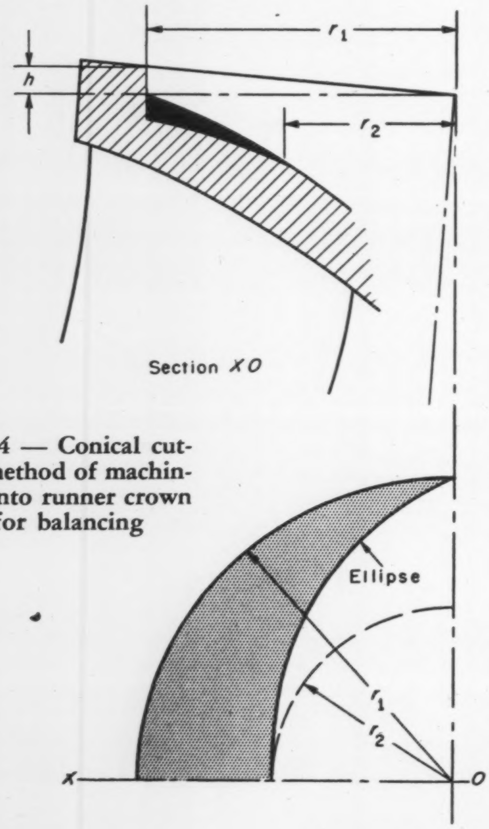


Fig. 4 — Conical cut-off method of machining into runner crown for balancing

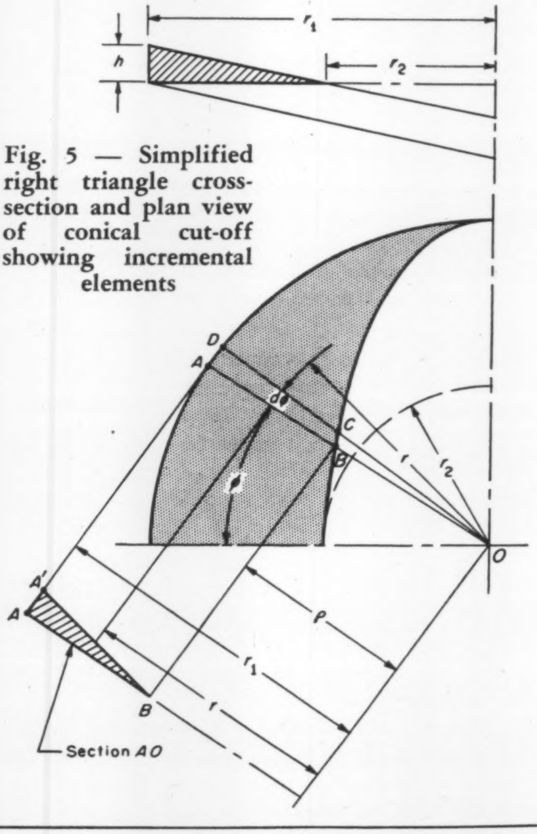


Fig. 5 — Simplified right triangle cross-section and plan view of conical cut-off showing incremental elements

and by rearrangement, the necessary radial offset, h, at radius r_1 is

$$h = \frac{8\, r_1\, U}{\pi\, \gamma\, (r_1^4 - r_2^4)}$$

The formation of a step at the radius r_2 is one disadvantage of this technique.

Conical cut-off: This third method is frequently employed to overcome the objectional feature of the second approach. In this technique the runner is fixed at a certain angle with respect to the axis of the lathe as done in the second method. However, the section of material removed is triangular as shown in *Fig.* 4, and the inner trace left after machining forms half of an ellipse.

Derivation of the equations for determination of volume, weight, and moment of material cut off the runner crown by this method is quite involved. However, without details of the mathematical development, the element of volume under the area *ABCD* in *Fig.* 5 is

$$d\,V = \int_{\rho}^{r_1} \frac{r\, h}{r_1 - \rho}\, (\cos\phi)\,(r_1 - r)\,(dr\; d\phi)$$

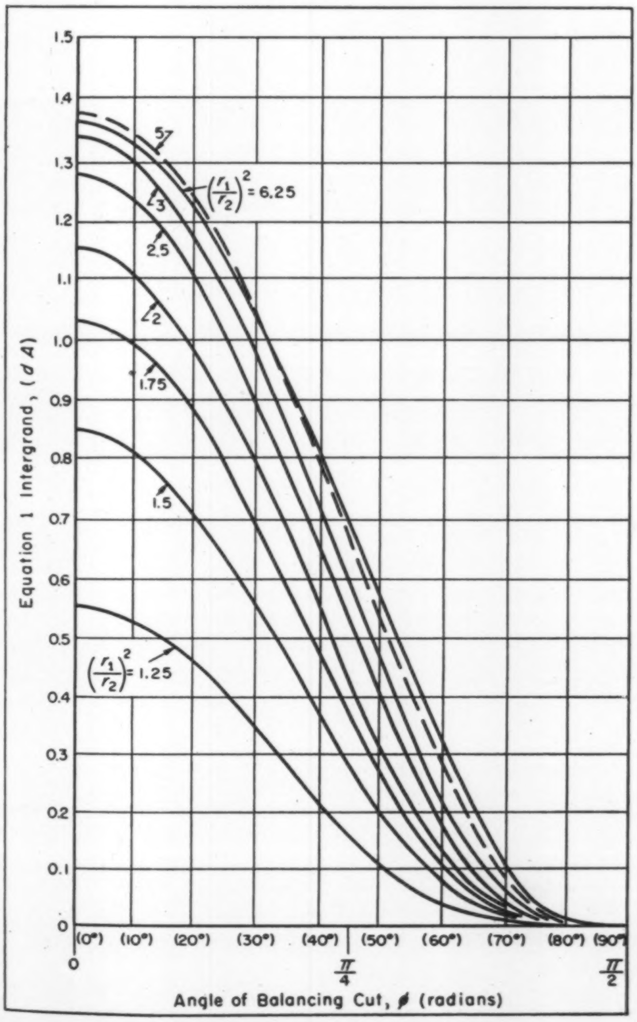
where

$$\rho = \frac{r_2}{\sqrt{1 - \lambda^2 \sin^2\phi}}$$

in which

$$\lambda = \sqrt{1 - \left(\frac{r_2}{r_1}\right)^2}$$

Fig. 6—Curves employed for the graphical evaluation of the integral in Equation 1



The total volume of material cut off is

$$V = \frac{h}{3} \int_0^{\pi/2} (r_1^2 + r_1\,\rho - 2\rho^2)\, \cos\phi\; d\phi$$

which, evaluated and expanded, becomes

$$V = \frac{h\, r_1^2}{3} \left[1 + \frac{r_2 \sin^{-1}\lambda}{r_1\,\lambda} - \left(\frac{r_2}{r_1}\right)^2 \frac{1}{\lambda} \log_e \left(\frac{1+\lambda}{1-\lambda}\right) \right]$$

$$= h\, r_1^2\, b$$

where b equals ⅓ the expression in the brackets. The weight of material removed is $W = V\gamma = \gamma h r_1^2 b$.

The element of moment of material under area *ABCD* is

$$dU = \gamma \int_{\rho}^{r_1} \frac{r^2\, h}{r_1 - \rho}\, (\cos^2\phi)\,(r_1 - r)\,(dr\; d\phi)$$

$$= \frac{h\,\gamma}{12}\, (r_1^3 + r_1^2\,\rho + r_1\,\rho^2 - 3\,\rho^3)\,(\cos\phi\; d\phi)$$

Substituting in the expression for ρ, the total moment of the material removed and hence the unbalanced moment is

$$U = \frac{r_1^3\, h\, \gamma}{6} \int_0^{\pi/2} \left[1 + \frac{r_2}{r_1} \frac{1}{\sqrt{1 - \lambda^2 \sin^2\phi}} - \right.$$
$$+ \left(\frac{r_2}{r_1}\right)^2 \frac{1}{1 - \lambda^2 \sin^2\phi}$$
$$\left. - 3 \left(\frac{r_2}{r_1}\right)^3 \frac{1}{(1 - \lambda^2 \sin^2\phi)^{3/2}} \right] \cos^2\phi\; d\phi \quad \ldots (1)$$

Then, letting A equal the value of the integral in Equation 1,

$$U = \frac{r_1^3\, h\, \gamma\, A}{6} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Finally, the radial offset h at radius r_1 is

$$h = \frac{6\, U}{\gamma\, r_1^3\, A}$$

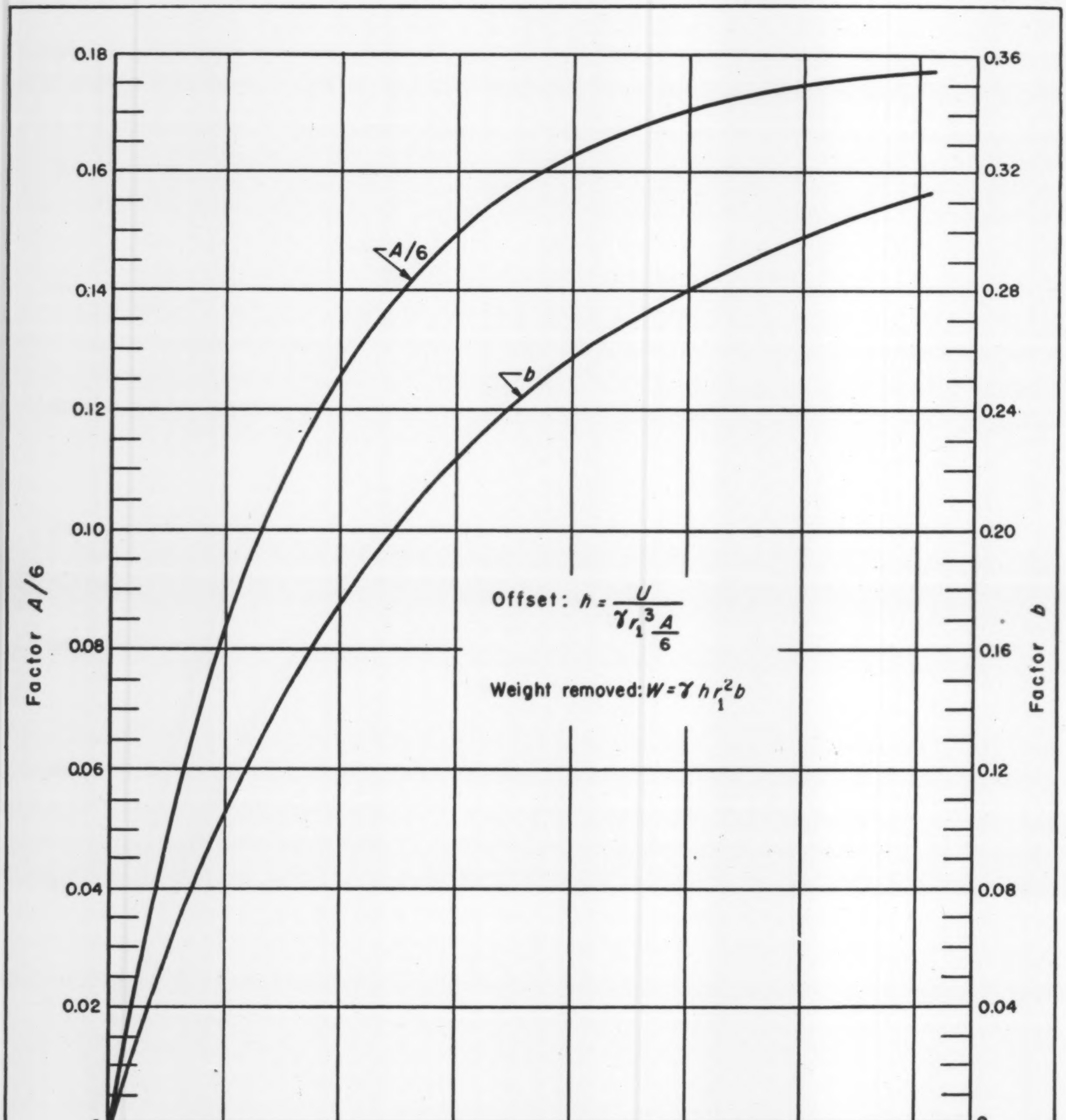
The last term in A is an elliptic integral and cannot be solved by ordinary elementary methods. It can be solved with tables for elliptic integrals but the method is rather cumbersome. Instead, the entire expression under the integral sign can be evaluated by graphical integration.

For a series of constant values of $(r_1/r_2)^2$, evaluations of the integrand were made for various values of ϕ, every 10 degrees, from 0 to 90 degrees and results are plotted in *Fig.* 6. The area under any particular curve represents the value of the integral A in Equation 2 for a given $(r_1/r_2)^2$. In evaluating the area the abscissa must be expressed in radians. The trapezoidal rule was used to determine the area under each curve with ordinates measured every 5 degrees. The summation technique provided an adequate degree of accuracy.

From values of A obtained from *Fig.* 6, a plot of $A/6$ for various radii ratios, r_1/r_2, is given, *Fig.* 7, to facilitate calculation of h. As stated previously the weight of the material removed is $W = \gamma h r_1^2 b$. Since b also involves tedious calculation, b versus r_1/r_2 is also plotted in *Fig.* 7.

Nomograms would further facilitate use of any of the balancing techniques discussed in this article. For adequate accuracy, however, charts would need to be restricted to moderate ranges of r_1.

Fig. 7—Graphs facilitating solution of equations for offset b and weight W of material removed



Engineering NEWS ROUNDUP

Engineering Grads Do Well Financially

According to a recent survey made by the Illinois Institute of Technology, members of its class of 1948 have bettered themselves financially about 100 per cent in the 5 years since graduation. Starting salaries were $3180 per year. Today 96 per cent of the graduates earn more than $4500 annually; 76 per cent earn more than $5500; 46 per cent make more than $6500; and 17 per cent are in the over-$7500 bracket. Average earnings are $6340 per year.

Present ages of the class range from 24 to 40 years with 29 being the average age. No correlation between age and income was discernible, however, a definite relation between salary and family status exists. Graduates with the larger number of dependents also have the larger salaries.

SEA-DART FLIES: Touching down for a landing, the XF2Y-1 Sea-Dart demonstrates the retractable hydro-skis which permit it to take-off and land on rough water. The world's first delta wing seaplane, the Sea-Dart has only recently flown for the first time and been demonstrated to the public

Red Carpet Ready For Largest Metal Show

"Metals Market Place of the World" is the theme featured at the 35th National Metal Congress and Exposition opening October 19 through 23 at the Municipal Auditorium in Cleveland.

Visitors and exhibitors will be able to move around in comfort on foam-rubber backed red carpet as they cover over 400 exhibits occupying 210,000 square feet—nearly five acres. Attendance is expected to exceed 75,000.

Thirty-eight technical papers are scheduled for presentation at the technical sessions of the ASM, held in conjunction with the National Metal Congress. Sponsors are ASM, AWS, AIMME and the Society for Non-Destructive Testing. Additional information on the Metal Show may be obtained from W. H. Eisenman, Managing Director, National Metal Congress and Exposition, 7301 Euclid Ave., Cleveland 3, Ohio.

Atom Power Participation Asked for Industry

The nation's atomic energy program now has reached the point at which broader participation by private industry would aid substantially in the harnessing of atomic energy for industrial and other nondefense purposes, an official of Sylvania Electric Products Inc. said recently. Walter E. Kingston, general manager of Sylvania's Atomic Energy Division, recommended changes in the Atomic Energy Act of 1946 that he said would permit effective participation by industry. He asserted that opening the field to private industry would insure important advances in the use of atomic energy for defense purposes.

He recommended that the Atomic Energy Act be changed to permit licensed private ownership and operation of plants for the recovery, manufacture, and sale of nuclear fuels and components containing source or fissionable material to government-licensed owners or operators of atomic power plants. He added that the Act should permit licensed fuel or component manufacturers, who are not necessarily owners or operators, to buy source and fissionable materials from the government or from private sources licensed to sell such raw materials.

The Act, according to Mr. Kingston, further should provide that inventions and discoveries, arising from activities sponsored with private capital, should remain by patent the property of the sponsoring party. The law, however, should provide for an irrevocable license to the U. S. government on any pa-

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tentable invention or discovery where such license is required for the national security.

In order that organizations which have been a part of the atomic energy program for the past several years do not gain an unfair advantage over those companies wishing to enter the field if the Act were changed, Mr. Kingston suggested a one- or two-year interim period during which a license to all patentable discoveries and inventions is made available to the government which, in turn, may sublicense qualified firms wishing to enter the field during the interim period. At the expiration of the interim period, standard patent law should apply.

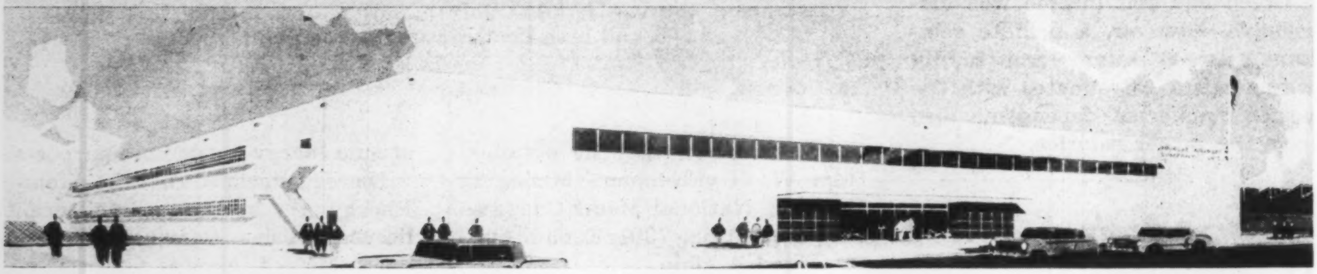
Professors Attend Industry Seminar at Westinghouse

Training of engineers for industry and management development as well as an exchange of problems common to both industry and the university, were highlights of a week-long seminar, "Recognizing our Responsibilities," held at the Westinghouse Educational Center in Pittsburgh for 36 college professors and instructors.

The seminar climaxed the sixth annual Industrial Experience Program for 18 of the professors who have been working all summer with engineers and specialists at Westinghouse plants. Purpose of the program is to give the professors first-hand information on industry which they can pass on to their students. The plan strengthens relationships with colleges and universities since the professors gain a viewpoint of the problems in industry from their own practical experience.

Under the Industrial Experience Program, professors and instructors from colleges as far north as Massachusetts and as far west as Nebraska were invited to participate. The list of schools invited is rotated each year in order to obtain greater participation from various sections of the country. Professors from 87 schools have participated in the six years that the program has been in progress.

ENGINEER'S DREAM: This $2 million building is expected to be ready for engineers of Douglas Aircraft Co.'s El Segundo Div. by February, 1954. The building will contain two engineering rooms an acre in size. Entire ceilings will be back lighted through luminous frost plastic. Automatically controlled window louvers will eliminate glare from the sun and the latest in air conditioning will be provided. Electronic computers for solving involved equations are also being installed



Metal Industries Set New Production Records

Aluminum and steel industries have broken all previous production records during the first half of 1953. Major uses of the metals are in civilian industry—the automotive industry ranking first in shipments of steel while the construction field is the largest consumer of aluminum.

Combined production of aluminum in the U. S. and Canada for 1953 is estimated at two million tons—about 75 per cent of the free world's output and over five times that of iron curtain countries. Primary aluminum production in the U. S. for the first half of 1953 reached 1,197,407,109 pounds—daily production averaging 7,000,000 pounds, a new peak. More primary aluminum has been turned out in the first half of 1953 than during the entire years of 1945, 1946 or 1947.

Military share of the total aluminum production accounts for about 30 per cent (half of this total going into military aircraft). The remaining 70 per cent is fanned out to the following principal industrial outlets: (1) building and construction field, (2) transportation, (3) electrical industry, (4) household appliances, (5) food and farming, (6) canning and packaging.

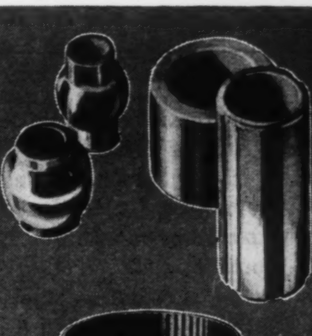
Over 114.6 million tons of steel have been poured in the past 12 months—more than any previous 12 months output of this or any other country. This total—about 2¾ times greater than Russia's expected output for 1953—includes 9,401,000 tons of ingots and steel for castings made in August—a production record for that month. In the first eight months of 1953, steelmaking furnaces poured 76,622,609 tons, the largest amount ever made in a comparable period of time.

Shipments of steel products in the first half of the year reached 42,356,861 tons—nearly 10 million

Are you looking for a Self-Lubricating Bearing?

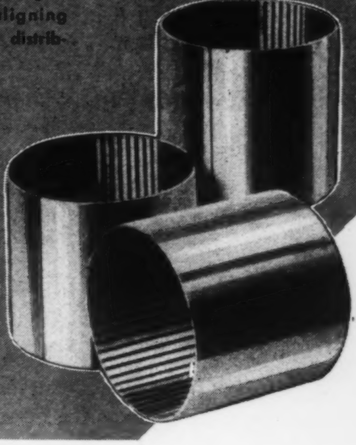
JOHNSON LEDALOYL Self-Lubricating BEARINGS

● Produced by powder metallurgy—molded pre-cast bronze alloy—these bearings are impregnated with oil. Made to order in large quantities of a size. A large selection of straight, flanged and self-aligning sizes available from distributor stocks.



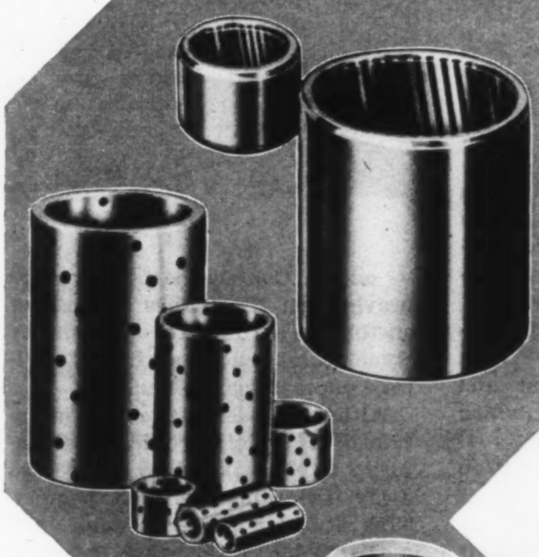
JOHNSON GRAPHITED SHEET BRONZE BEARINGS

● Serrated type. Made to order in wide range of sizes. Low cost in quantities of a size.



JOHNSON GRAPHITED CAST BRONZE BEARINGS KR SERRATED TYPE

● Provides 40 to 45% graphite contact with shaft, increasing slightly with wear. This type is a standard stock item in over 200 sizes, available from Johnson Distributors. Other sizes made to order.



PLUG TYPE GRAPHITED CAST BRONZE BEARINGS

● Stick graphite is forced into drilled holes. Made to order in any size, or produced from any of 900 Standard Stock Size Johnson GP Bearings.

OIL GROOVE TYPE GRAPHITED CAST BRONZE BEARINGS

● Oil grooves serve as recesses to hold graphite. Made to order in any size, or produced from any of 900 Standard Stock Size Johnson GP Bearings.

Oil groove type

JOHNSON GRAPHITED BRONZE BEARINGS and JOHNSON LEDALOYL (Powder Metallurgy) BEARINGS meet such requirements. They were developed primarily for applications where lubrication is difficult or likely to be neglected. Where shaft speed is too slow or the temperature too low to sustain an oil film, use a Johnson Graphited Bearing. If high operating temperatures may burn out oils and greases, your answer may be a graphited bearing. They are recommended, too, where lubricants may damage goods or foods in process, where dripping oil cannot be tolerated, and in certain underwater applications. Johnson Ledaloyl Self-Lubricating Bearings are impregnated with oil, which is metered to the shaft in operation, reabsorbed when at rest. They are especially desirable for sealed-in applications. Johnson Engineers will gladly help you select the correct sleeve bearing for the job. Write for full information.

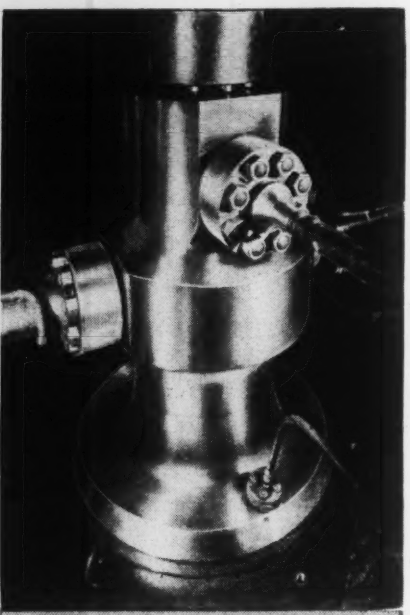
JOHNSON BRONZE COMPANY
525 South Mill Street • New Castle, Pennsylvania

JOHNSON B BEARINGS
Sleeve-Type

OTHER JOHNSON BEARING TYPES . . .

General Purpose (GP) • Electric Motor (EM) • Universal Bronze Bars • Babbitt Metal tons higher than that shipped in the first half of 1952. More steel was shipped in June to ordnance and other military classifications than in any other month since the end of World War II.

Production of stainless steel an heat resisting steels reached a new high in the first half of 1953 at 594,203 net tons—an increase of 181,617 tons over the first half of 1952.



LARGE STAINLESS FORGING: Two electric furnace heats were required to make the ingot from which this head for a liquefactor convertor was forged. Believed to be the largest stainless steel forging ever produced, it is 51 inches in diameter at the largest point, stands 6½ feet high and weighs about 10 tons

Magnet Research Sponsored by Air Force

A comprehensive research program on magnetics to improve military air and ground devices using magnets was announced recently by the Air Force. The program, to be carried out by the Indiana Steel Products Co., will include both basic and applied research.

Basic research will be concerned with the nature of magnetism, possible new magnetic alloys, metallurgical factors affecting magnetic characteristics and the theory of magnetic phenomena. Applied research will be concerned with the properties of known ferro-magnetic materials, chemical and physical changes brought about by aging of metals and the effect of variations in analysis and manufacturing techniques on aging.

Design and application research will also be included in the program. Development of comprehensive design factors for magnetic circuits, determination of magnetic characteristics of magnetic materials and the study of existing designs to improve reliability and efficiency, and conserve weight, space and critical materials are typical design and applications research projects.

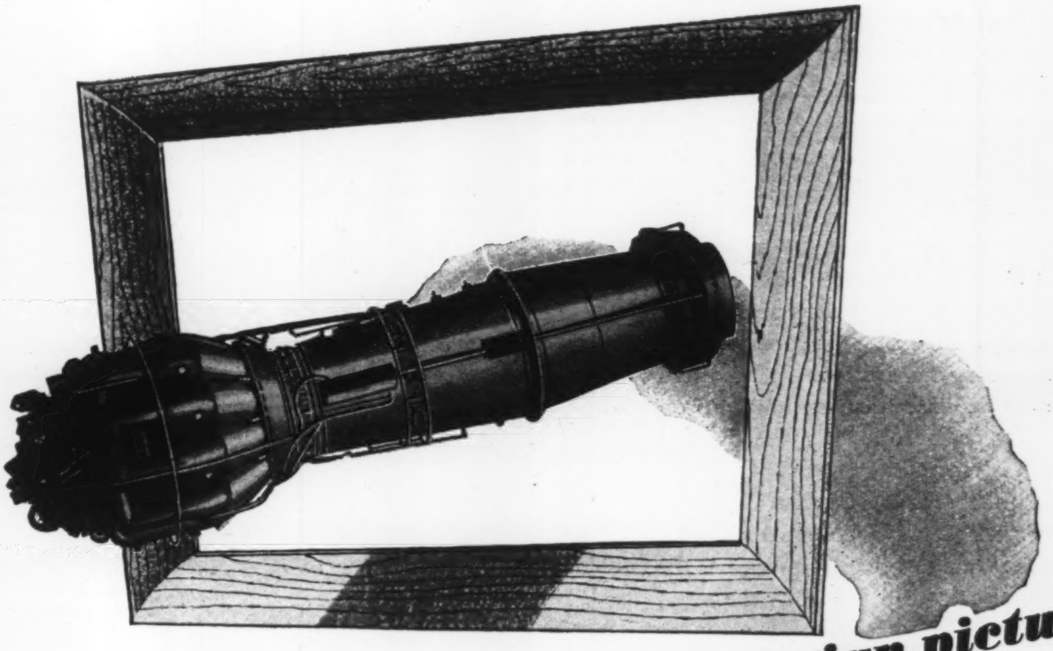
SUBMINIATURIZATION: Jeweler's tools and magnifying glass are necessary to assemble complicated but tiny electronic control equipment at the Ryan Aeronautical Co. Assemblies such as this are used to control guided missiles and pilotless aircraft such as the Ryan Firebee target plane

Airlift Speeds Gear Engineers

It may still be true that if you make a better product the world will beat a path to your door. However, a Sterling, Ill. gear manufacturer believes in just the reverse—beating a path to customer's doors by way of the airplane.

J. C. Shomaker, president and founder of the Rynel Corp., which manufactures fine-pitch gears, conceived the idea of air operation for customer service and engineering while overseas during the last war. A fleet of five aircraft is owned by the company—two twin Beechcrafts, one Beech Bonanza, a Cessna 195 and a Ryan Navion. More multi-engine craft will soon be added. Conference facilities are provided in the planes for use of customers enroute to or from the Rynel plant, and a staff of 3 full-time pilots is maintained.

Although sales offices are maintained in principal cities, the majority of plants serviced are located away from metropolitan centers. This situation is met through daily air trips by Rynel sales and engineering staff to customer's plants, or by picking up officials and engineers at a customer's plant and flying them to Sterling.



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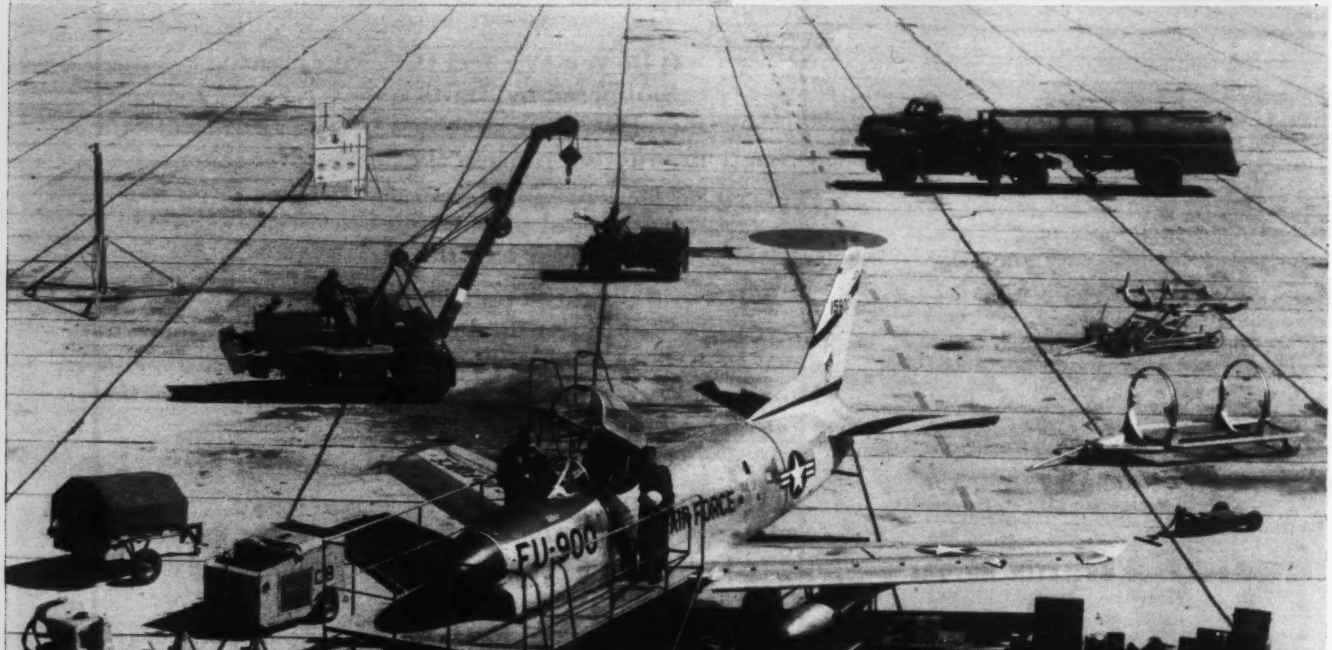
THEN AND NOW: Early aircraft required few tools for their maintenance. The photograph, right, shows the essential tools carried by the barnstorming mechanic for maintaining an airplane in the field during an exhibition or barnstorming tour during the fifteen to twenty years following the Wright Brothers' first flight. Modern, more complex military air craft, typified by the North American Sabre jet below require many more tools and men to keep them in flying condition. Perhaps typical of the change is the replacement of the funnel by the umpteen gallon fuel truck



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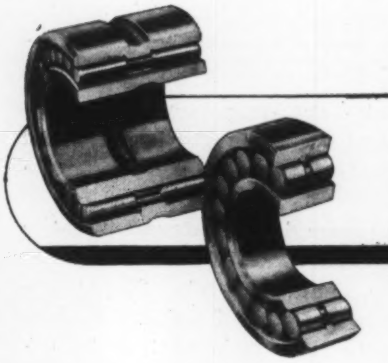


Over 33% Greater Capacity For The Same Size

There is a challenge facing manufacturers today to build smaller and more compact machines with extra precision and to combine more operations in each machine. This makes the selection of the proper bearings extremely important. A definite plus factor in this selection is the availability of a precision bearing that will deliver extra load carrying capacity in a minimum amount of space.

Obviously roller bearings, and particularly those of the small (needle) roller type occupy far less bearing space for equivalent capacity than ball bearings. Roller bearing capacity is built up in proportion to the effective race and roller contact provided. Thus a full type roller bearing *without space wasting cages* should provide the greatest capacity of any type of anti-friction bearing. However, to offer a perfect bearing the resulting full roller complement must be prevented from skewing and binding where misalignment occurs in the application.

The Guiderol bearing is the accepted answer to all these requirements considering precision, load capacity, long life, versatility of mounting, and ease of lubrication. Published ratings show the Guiderol CT Series bearing has over 33% greater load carrying capacity than the average of the four highest rated interchangeable bearings. As a result, a Guiderol bearing at least one size smaller can often be substituted with the necessary shaft and housing requirements reduced in size and cost.

Bearing	McGill Guiderol No. GRI-209	Brand A Bearing	Brand B Bearing	Brand C Bearing	Brand D Bearing
Published Load Rating	8370 lbs.	6700 lbs.	7000 lbs.	5520 lbs.	6080 lbs.

Capacities at 2500 hours average life at 100 RPM

How Rollers Are Guided

In the Guiderol bearing design the grooved rollers with full race width contact are prevented from skewing by a center guide rail. Normally the rollers run on a true axis — not contacting the rail and thus need no correcting. (Fig. 1) Should misalignment cause a shift off center (Fig. 2) the leading end of the roller is retarded by contact with the rail at location Y. The trailing end catches up, relieving the rail contact, and the roller then resumes normal operation.

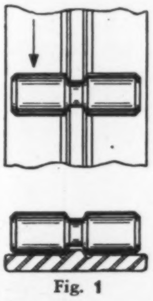


Fig. 1

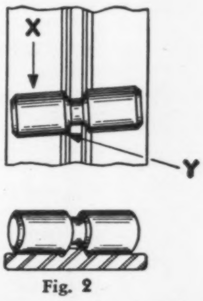
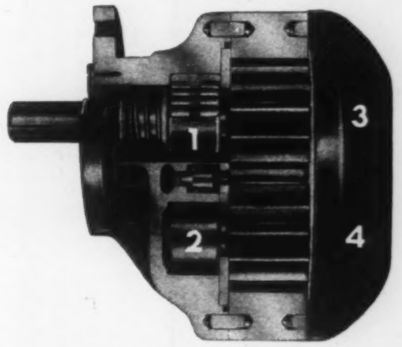
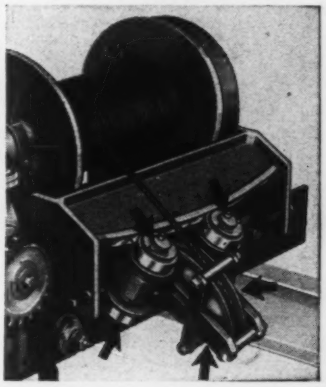


Fig. 2

Typical GUIDEROL® Bearing Mountings

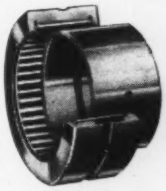


On a Hydreco Gear Pump Idler and Drive Shaft, 4 Guiderol bearings are used. The longer rollers of the Guiderol bearings are effective virtually to the edge of the races. This gives substantial support close to the gear and materially reduces shaft deflection.

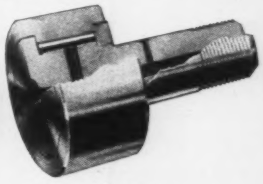


Four Guiderol bearings support and guide an automatic spooling attachment across the face of the reel track on a 20,000 pound Gar Wood Reel-Rite Winch. The guided roller principle prevents skewing of rollers in the 4 vertically mounted bearings even with a 10,000 pound angular load per bearing. A fifth Guiderol bearing in the sheave provides added stability and eliminates binding due to off-center loading.

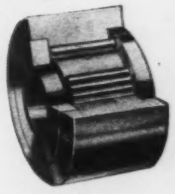
MULTIROL® Bearings



SE Series



CF Series



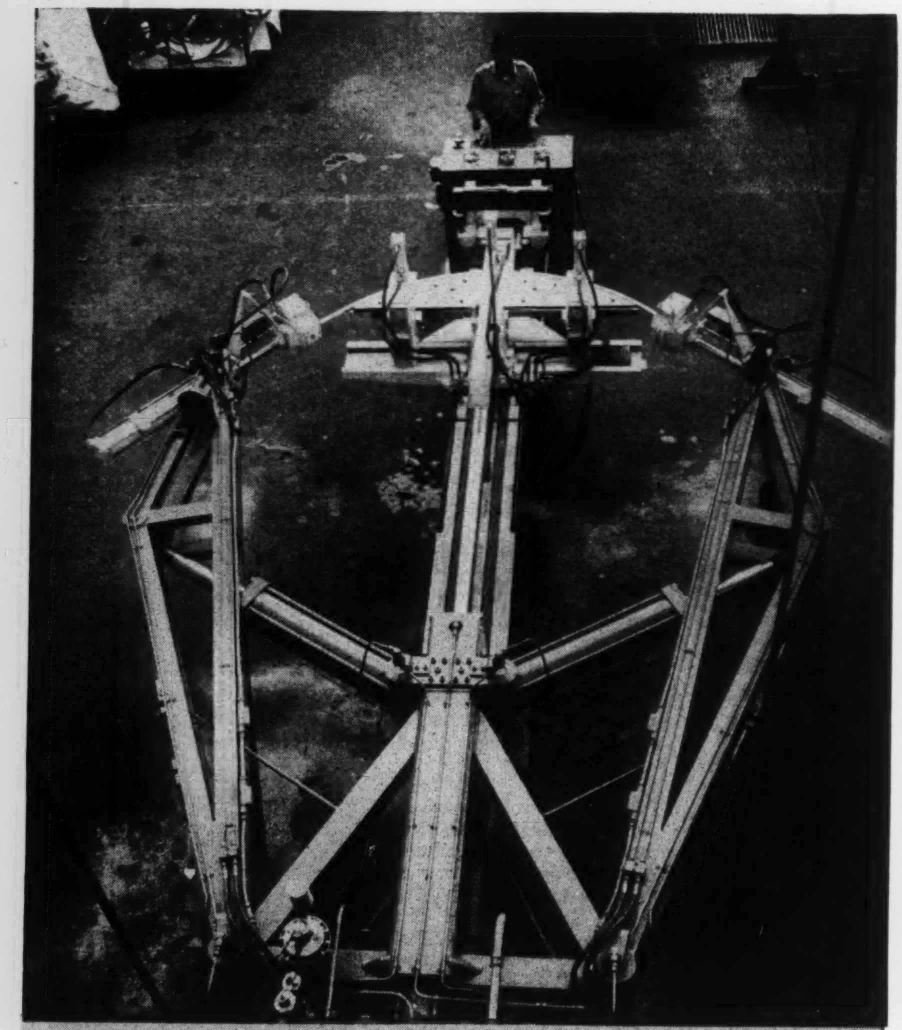
CYR Series

A new 140-page Bearing Reference Guide complete with 30 pages of vital engineering data has just been released by the McGill Manufacturing Company.

It has the full story on the advantages of Guiderol Bearings and in addition contains complete information on the well-known Multirol CF, CYR and SE Bearings. *Send now for your copy of the McGill Catalog No. 52.*

McGILL® — Precision Bearings

McGILL MANUFACTURING COMPANY, INC.
200 N. Lafayette Street, Valparaiso, Indiana



MECHANICAL LOBSTER is really a Sheridan stretch press used to wrap-form extrusions for Boeing C-97 fuselages. Grasping the ends of the extrusions in its powerful claws, the machine forms large-radius contours at Ryan Aeronautical Co.

Fastest Computer For Oak Ridge Labs

A new high-speed general-purpose digital computer is to be installed at the Oak Ridge National Laboratory this fall. Claimed to be the fastest of its type in the world, the computer was designed and constructed at the Argonne National Laboratory.

Built at a cost of $350,000.00, the ORACLE (Oak Ridge Automatic Computer, Logical Engine) has an internal memory system which can receive, retain and process as many as 2048 twelve-digit decimal numbers. Additionally an auxiliary memory system will store four million words, each word equivalent to a 12-digit decimal number. Storage devices are magnetic tape and eighty 3-inch cathode ray tubes.

A difficult mathematical problem which would take from 5 to 6 years for two mathematicians to solve using desk-type electric calculators can be solved by the ORACLE in 20 to 30 minutes. Addition of two 12-digit numbers requires 5 microseconds. Multiplication of the same numbers requires a little less than ½-millisecond. Subtraction, division and other arithmetical and logical operations can also be performed. Results are on paper tape which is translated into numbers and characters by a teletype page printer.

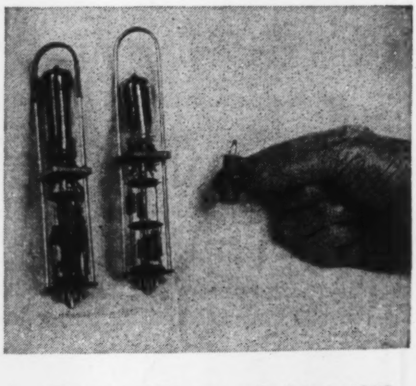
A complex instrument, the ORACLE contains 3500 electronic tubes, approximately 20,000 resistors and about 7 miles of wiring. Despite this, it is said to be exceedingly compact.

Magamp Used In Miniature Computer Element

A new miniature computer element employing a half-pulse magnetic amplifier weighs 1/5-ounce, has a total volume of ¼ cubic inch and uses only ¼-watt of electric power. The tiny unit, developed by Naval Ordnance Laboratory's Aplied Mathematics Div. in co-operation with the Minnesota Electronics Corp. is called a Magnetic Decision Element and can replace two vacuum tube stages in the 0—200 kilocycle range of operation.

Functions such as high-speed storage, coincidence switching, arithmetic addition, precision delay and high speed analog-to-digital conversion can be carried out by the elements, either alone or in combination with a small number of others. Repeatability, ruggedness and small size make the element particularly useful in weapon computer systems; however, it can be used in other applications where its frequency range is suitable. Certain promising materials are now being considered to raise the operating range to 1 megacycle.

Two vacuum tube stages, left, can be replaced by tiny Magnetic Decision Element, right. Volume of new device is ¼-cubic inch



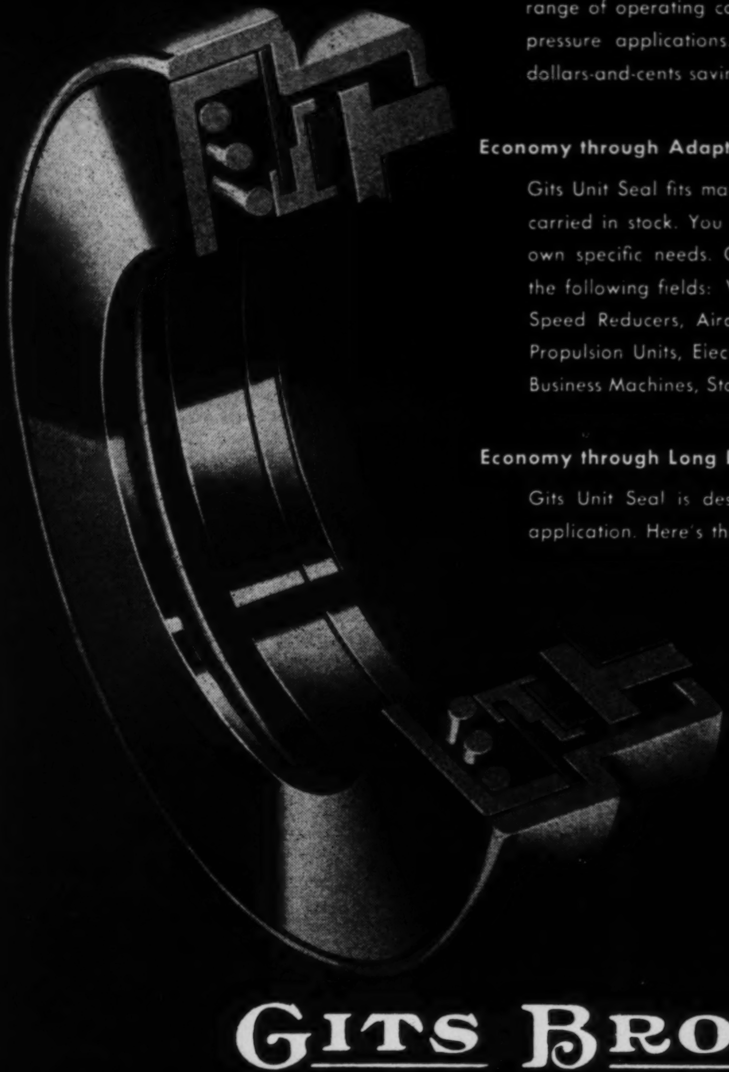
Specify

GITS *Unit* SEAL

Result:

Economy

"Economy . . . counts not in savings but in selection."—*Edmund Burke*



Economy through Efficiency

Gits Unit Seal proves itself in dependable performance over a wide range of operating conditions—including extra-high speed, heat and pressure applications. Operation at peak efficiency always means dollars-and-cents savings.

Economy through Adaptability and Versatility

Gits Unit Seal fits many applications as a standardized item actually carried in stock. You harness the savings of mass production to your own specific needs. Gits Unit Seal already has wide application in the following fields: Washing Machines, Disposal Units, Gear Motors, Speed Reducers, Aircraft Turbine Pumps, Accessory Drive Units, Jet Propulsion Units, Electrical Power Equipment, Automotive Accessories, Business Machines, Standard and Special Machine Tools.

Economy through Long Life

Gits Unit Seal is designed for maximum life in any recommended application. Here's the real "proof of the pudding" in saving money.

Write Today For FREE Illustrated Brochure, or send us your seal problem. Our experienced engineering staff is at your service.

*Cartridge Seal . . . requiring only 25% more space than lip-type seals.

GITS BROS. MFG. CO.

1868 S. Kilbourn Avenue
Chicago 23, Illinois

Miniature Metals Mill Produces Precision Stock

For the development of new alloys for watch parts, Hamilton Watch Co. has installed under one roof a complete miniature metals mill. One of the materials is Elinvar-Extra, a nickel-base alloy with an essentially constant thermal coefficient of elastic modulus. Used for hairsprings in self-temperature-compensated watches, it is drawn to section sizes as small as 0.0007-inch by 0.0040-inch for ladies' models. Another is a new mainspring material known as Dynavar which is a high-strength fatigue proof cobalt-base alloy.

Parts are produced entirely in plant—from ingot pouring to final parts fabrication—to the close tolerances required in interchangeable precision products.

Facilities developed for this work as well as for the production or working of stock needed for other types of parts have recently been made available by Hamilton to other industries having special alloy or stock-processing needs in small volume.

All under strict quality control, operations which can be performed in the complete miniature mill at Lancaster, Pa., are: melting and casting ingots of special alloys; forging bars or rods from ingots; hot or cold rolling strip of special alloys; rerolling customer's strip; processing special alloy wire; redrawing, straightening and cutting customer's wire; slitting strip; and bright heat treating small parts.

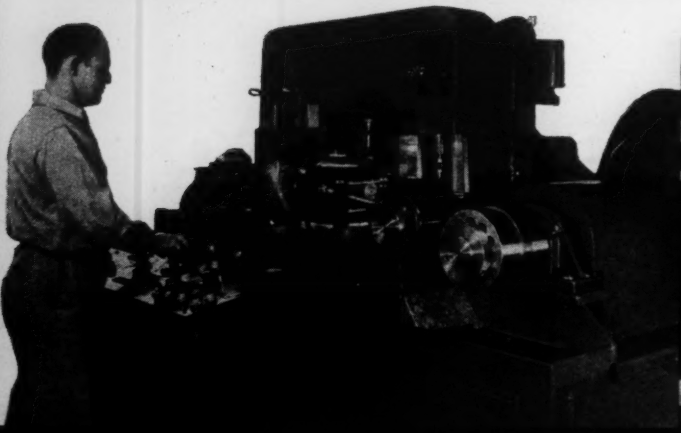
(1) Pouring an ingot from a high-frequency induction furnace. Capacity of the furnace permits melting and casting 3 to 25-pound ingots. Composition of special alloys can be held to the same close specifications required of hairspring and mainspring alloys.

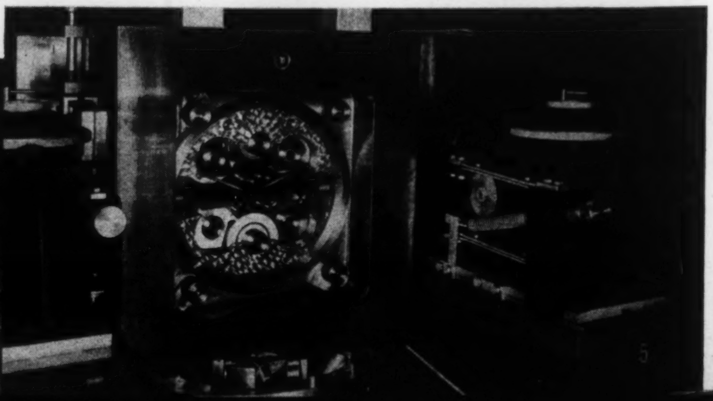
(2) Hot rolling to commercial tolerances is done on this heavy mill. Strip to 4 inches wide and 16 feet long can be processed

(3) This specially designed slitting mill can slit most materials to widths ranging from 0.040 to 4 inches wide within a tolerance of ±0.001-inch

(4) Precision cold rolling to tolerances of ±0.0001-inch is done on this Sendzimir mill. Strip as thin as 0.001-inch can be economically produced. Finished strip is flat, having no camber or heavy center. Surface and edges are smooth

(5) Heart of the Sendzimir mill. Work rolls are pictured with the door of the roll block open. One of the work rolls has been removed from the cluster





(Advertisement)

Facts about *HELI-COIL* inserts you should know

What they are

*Heli-Coil** screw thread inserts are precision formed coils of stainless steel or phosphor bronze wire. Wound into tapped holes, they form permanent, non-corrosive, strip-proof threads of astonishing strength. Available for National Coarse, National Fine and Unified threads, pipe threads and spark plug threads. They are made in all standard sizes and lengths for assemblies requiring Class 3, 3B, 2 or 2B fits.

What they are for

AS ORIGINAL COMPONENTS: *Heli-Coil* inserts are used to provide stronger, lighter fastenings, corrosion-proof, wear-proof threads in all assemblies.

FOR PRODUCTION SALVAGE: When conventional tapped holes are damaged in production, restore them on the line with *Heli-Coil* inserts. Get better-than-original strength with no increase in screw size and no tell-tale signs of rework.

FOR SPEEDY REPAIRS: When tapped threads wear, strip or corrode in service, renew them in minutes on location in shop or field with *Heli-Coil* inserts. No welding—no plugging—no secondary machining—no oversize screws.

How they work

Holes are drilled and tapped as you do for ordinary threads—then *Heli-Coil* inserts are wound into tapped holes by hand or power tools. Install in a few seconds, assure thread protection forever. Can be used in any metal wood or plastic.

No other method is so simple, effective and practical.

What they do for you

Heli-Coil inserts *save money* because they strengthen threads and make *fewer* smaller fastenings do the same holding job. They make *lighter* bosses and flanges practical and they *save weight* in two ways: (1) by permitting use of cap screws, instead of bolts and nuts; (2) by allowing use of smaller, shorter, fewer cap screws. *Heli-Coil* inserts *protect* your product from thread wear, galling and stripping for life in every kind of metal, in plastics or wood. They preserve customer good-will by preventing product failure, due to thread fault. *Heli-Coil* inserts improve the end product, cut rejects, salvage threading errors.

Best time to put *Heli-Coil* inserts benefits to your use is right at the designing board, as many leading manufacturers are doing. But to convince you of their many advantages ask for a working demonstration right on your production line. Write today! Complete information and engineering data is available in the *Heli-Coil* catalog. Use Coupon!

*Reg. U. S. Pat. Off.

Approved for All Military and Industrial Uses

7 savings wrapped up in HELI-COIL inserts

These savings are multiplied into major profits this simple way

Use *Heli-Coil** Inserts to:

1. *Save* money by using fewer and smaller screws to do the same holding job.
2. *Save* material—lighter bosses, thinner wall section, smaller flanges.
3. *Save* weight and reduce bulk in assemblies.
4. *Save* assembly time by using cap screws instead of nut-and-bolt assemblies.
5. *Save* rejections in production. Threads damaged on the line are quickly repaired. You save time. Reduce scrap.
6. *Save* on field service costs. No field damage to threads—fortified by *Heli-Coil* inserts.
7. *Save* customer good will by eliminating product failure due to thread fault. Every thread in your product is made stronger, longer wearing with *Heli-Coil* insert protection.

Use the handy coupon to get *free sample Heli-Coil* inserts plus all the data you need to design these savings into your product.

HELI-COIL CORPORATION
130 SHELTER ROCK LANE, DANBURY, CONN.

☐ **Send samples and Handbook 652, a complete design manual.**
☐ **Send samples and put my name on list to receive "Heli-Call," case history periodical.**

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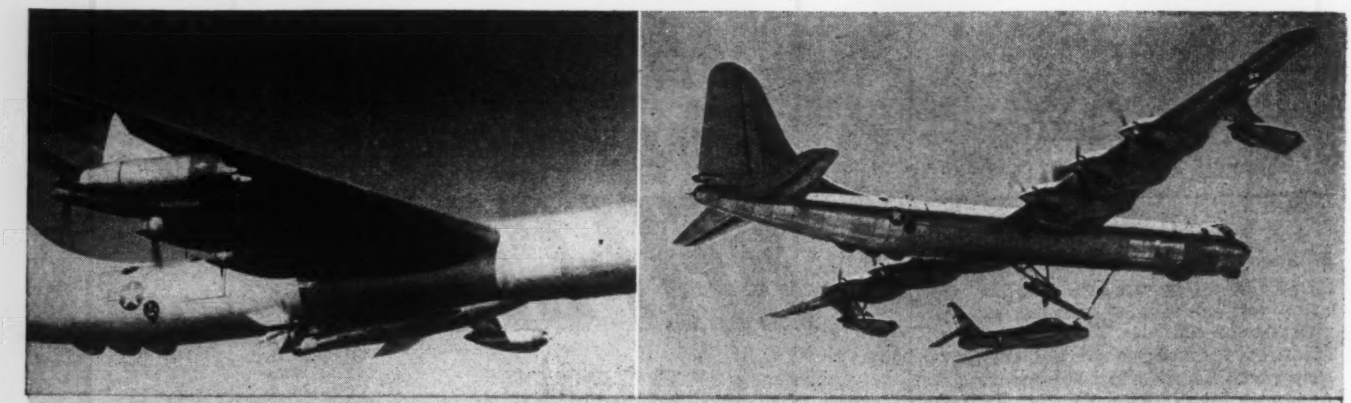


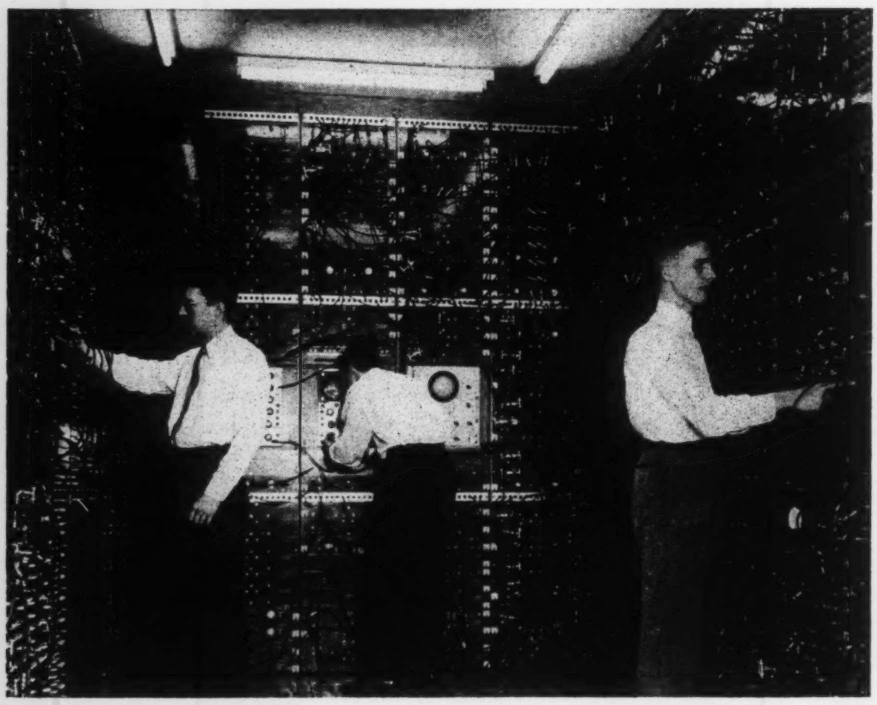
PARASITE PLANE: Successful development of the B-36 bomber as a carrier for reconnaissance fighter-type aircraft was recently announced by the Air Force's Research and Development Command. An F-84F is shown stowed within the bomb bay of a B-36, left. An approach for an in-flight "landing" is being made at the right. The aircraft can take off and land as a single unit. Also, the "parasite" can be released and retrieved by the "mother" plane during flight

Computation Service Offered

High-speed computation services, performed automatically on the Burroughs Laboratory Computer—Model I, are now available to business, manufacturing, trade and scientific organizations at the Philadelphia Research Center of Burroughs Corp. Developed and improved over the last two years for laboratory study, this electronic digital computer has been proven on a regular schedule of computations. Test problems for outside organizations have included turbo-engine design and performance calculations; pipe stresses for chemical processing plants; optical ray tracing; antenna calculations; and statistical correlations.

General features of the computer include: magnetic drum memory systems; punched paper tape input and output facilities, including photoelectric read-in; and extensive checking circuits to avoid error. The computer is largely made up of more than 750 standard electronic building blocks, known as pulse-control units, which are widely used as test equipment in electronic research on computers. The time required for an addition in the computer is 0.017-second; for multiplication, 0.050-second.

Laboratory set-up of computer allows reconnection of components to solve a wide variety of problems by appropriate programming



Ceramic coatings to increase high temperature resistance of high and low alloys, carbon steel and aluminum are now being offered by General Ceramics and Steatite Corp. Ceramic coatings for metals have proved to be of value where extremely high temperature and severe operating conditions are encountered.

Non-Inflammable Hydraulic Fluid

A new hydraulic fluid combines maximum fire resistance with top hydraulic efficiency. Known as "Houghto-Safe" the water-base material is rated as an acceptable hydraulic fluid from the fire hazard standpoint by the Factory Mutual Engineering Div. of Associat-

(Advertisement)

Special Treatment Withstands Condensation of Moisture On Motor Windings at -38°

Industrial trucks built by Crescent Truck Company, Lebanon, Pennsylvania, for use in the plant of Polar Cold Storage Company, are specially engineered for the application. Trucks are built with an extremely short turning radius to permit ready maneuvering in the narrow aisles necessary to conserve space in a cold storage warehouse. Special treatment of the windings on the drive and pump motors is also necessary to withstand condensation of moisture with the trucks entering and leaving the 38 degree-below-zero refrigerated areas.

Crescent lift trucks used in this cold storage warehouse are powered by Star-Kimble traction motors with windings treated to prevent condensation of moisture.

Drive and pump motors for this severe service were engineered and built by Star-Kimble. Motors are of the ET type, designed for 30-volt storage battery operation, and use Class B insulation to provide high capacity and compactness.

The Class B insulation is treated with a varnish formulated to withstand condensation of moisture on the windings. The Star-Kimble motors on these Crescent trucks have been in service for periods as long as five years (9 hours a day), under severe loading conditions and extremes of temperature, with little or no maintenance.

Information on Type ET d-c traction and pump motors for industrial truck service is available from Star-Kimble Motor Division of Miehle Printing Press and Mfg. Co., 201 Bloomfield Avenue, Bloomfield, New Jersey.

Precision
Drag-free
STOPS!
STARTS
THROUGH MILLIONS OF CYCLES

WITH STAR-KIMBLE BRAKEMOTORS

Stopping of a Star-Kimble Brakemotor is split-second in action, precisely timed by simple adjustments. Quiet, too — no lining screech. Low lining pressure, evenly distributed, assures long brake life. Brake is self-adjusting to compensate for lining wear — ruggedly built to withstand shock and vibration.

Braking force is spring applied, magnetically released. No linkages to cause lost motion or friction.

Starting of a Star-Kimble Brakemotor is smooth and free from drag. Small magnetic air gap assures quick brake release without high inrush current.

And Star-Kimble Brakemotors *maintain* this fast, smooth stop-start operation through millions of cycles with little or no maintenance attention. Brake and motor are *designed* together to *work* together as a single compact unit. One manufacturer, one responsibility — backed by years of experience. For details on construction, motor ratings and braking torques, write for Bulletin B-501-A.

Standard and special motors of all types, 1 to 600 hp; Marine motors ½ to 600 hp; generators and motor-generator sets, 1 to 500 kw.

STAR-KIMBLE
MOTOR DIVISION OF
MIEHLE PRINTING PRESS AND MFG. CO.
201 Bloomfield Avenue Bloomfield, New Jersey

ed Mutual Fire Insurance Companies.

Lubricating ability equal to that of high grade petroleum hydraulic oils has been demonstrated in tests. It will not freeze and is easily pumpable at working temperatures down to zero F. Other properties of this product of E. F. Houghton & Co. are high oxidation stability and a viscosity index of 150.

AIEE Holds Machine Tool Conference

The sixth annual American Institute of Electrical Engineers' Special Conference on Machine Tools will be held Oct. 14-16 in the Hotel Cleveland, Cleveland, Ohio. Cosponsor of the conference is the Cleveland Section of AIEE.

A series of eleven technical papers will be presented dealing with such subjects as electronic drives, automatic machine control, economics of control devices, tracer controls, clutches and dynamic brake motors. Panel discussions, inspection tours of industrial plants in the area, a banquet and luncheon are also planned. Speaker at the banquet on October 14 will be Frederick S. Blackall Jr., president of the American Society of Mechanical Engineers.

Physical testing service is now available to industry at the Weber Instrument Corp. Testing Laboratory in Detroit. Services include strain-gage and Stresscoat work, vibratory fatigue testing and dynamometer testing. Laboratory staff members are technicians and engineers with a combined experience of thirty years in the stress analysis field.

New Surfacing Technique

A new method of treating metals is said to produce surfaces of greater uniformity than conventional surfacing techniques. Known as "Metablast" the process consists of shooting a specially developed abrasive suspended in a liquid at high pressure against the metal surface to produce identical tiny pits. Size of the pits can be varied as desired and accurately duplicated. Tolerances of 0.0001-inch, not obtainable with sand or shot blasting, wire brushing or chemical treatment, are readily maintained, according to the manufacturer.

Suggested uses for the process, developed by American Metaseal Manufacturing Corp., include removal of rust, dirt and scale; mold and die surface conditioning; treating of tool, gear and bearing surfaces to give increased life, and preparation of metals for painting, bonding, plating and buffing.

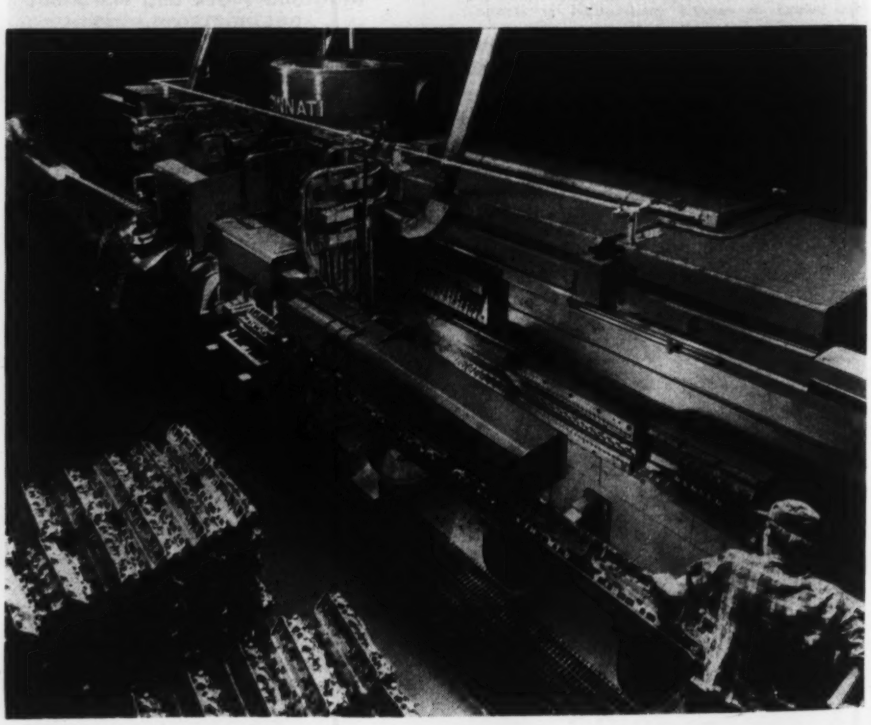
Largest universal testing machine ever built has been ordered by Lehigh University for delivery by February 1955. Although the machine will be the third of 5-million pound capacity built by Baldwin - Lima - Hamilton Corp., its height of 57 feet is 8 feet more than the next highest of this capacity.

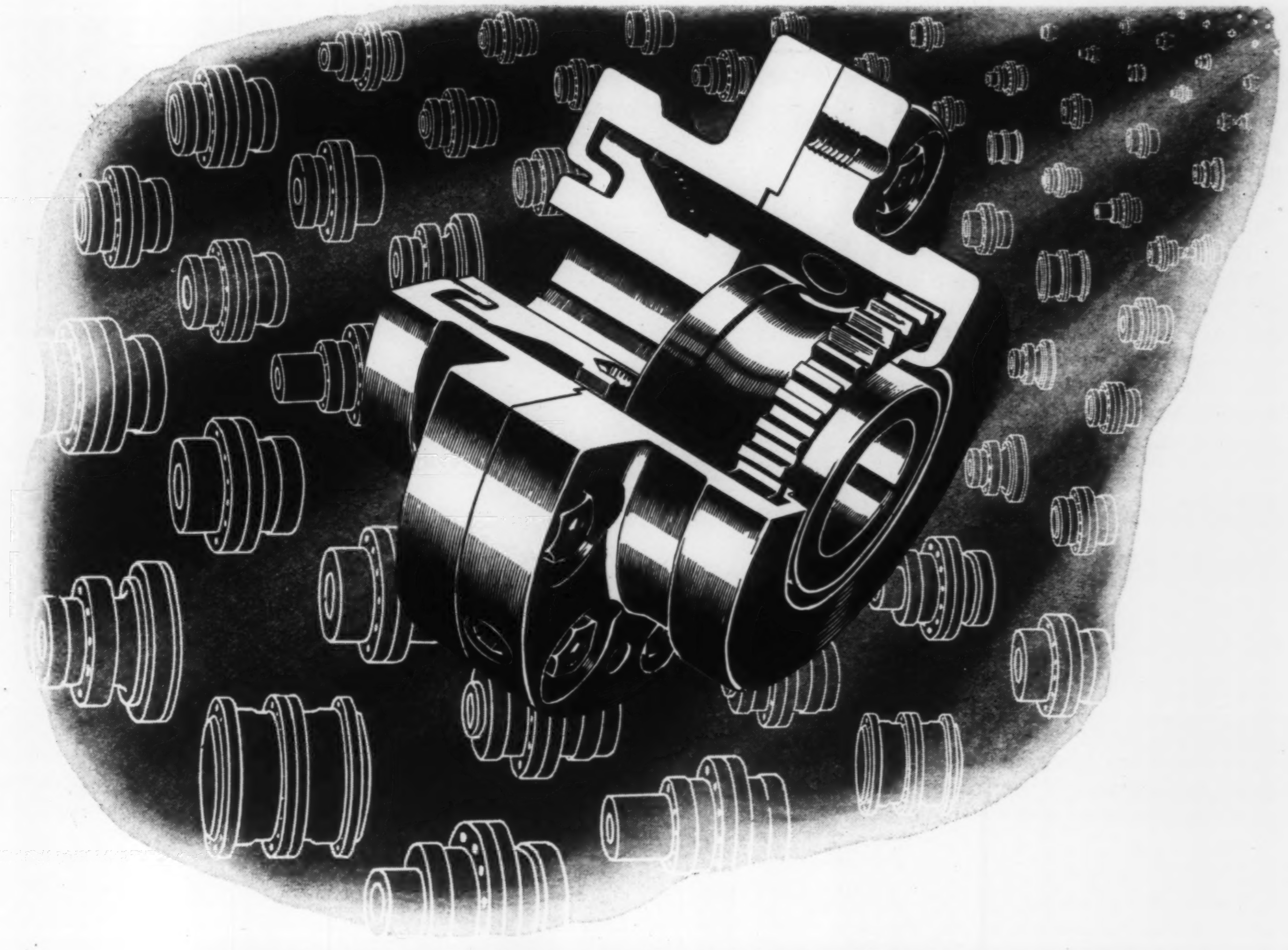
Clear space in the machine for tests in tension or compression is 40 feet vertically and 10 feet between the columns. Maximum test stroke is 36 inches.

Ceramic Magnets Have High Coercive Force

A new ceramic permanent magnet material features magnetic and physical potentials applicable in many fields. The material, lightweight, magnetically-hard Cromag, has high coercive force and a suitable residual induction to cover a variety of applications. Stability due to the high coercive force is claimed by its producer, Henry L. Crowley & Co. Inc., to be superior to previous materials, making it

GIANT BROACH: Weighing more than 75 tons and 45 feet in length, this giant machine automatically broaches three sides of a Buick V-8 cylinder head to the required tolerances. Grid at front of machine is for scrap which drops through onto a conveyor for a ride to the scrap bins





Hundreds of thousands of installations prove . . .

FAST'S Couplings are FIRST!

There's no stronger endorsement of Fast's Couplings than the close to three-quarter million Couplings installed in the 33 years since their design revolutionized the power coupling business!

Trouble-free performance that saves down-time, maintenance, and money led to that record. And, whatever your coupling applications, it's a guarantee of what *you* can expect from Fast's! Fast's Couplings give you *rugged construction* . . . because their original design has been maintained without basic change or sacrifice in size or materials. Fast's Couplings give you *lowest cost per year* . . . because they usually outlast the equipment they connect. And Fast's Couplings give you the benefit of Koppers *free engineering service* . . . assuring you of the right coupling for any job and the right solutions to tough coupling problems.

Write today for full details to KOPPERS COMPANY, INC., *Fast's Coupling Dept.*, 340 Scott St., Baltimore 3, Maryland.

KOPPERS ®

THE ORIGINAL

FAST'S Couplings

METAL PRODUCTS DIVISION • KOPPERS COMPANY, INC. • BALTIMORE, MD. This Koppers Division also supplies industry with American Hammered Industrial Piston and Sealing Rings, Koppers-Elex Electrostatic Precipitators, Aeromaster Fans and Gas Apparatus.

Engineered* Products Sold with *Service

KOPPERS COMPANY, INC., *Fast's Coupling Dept.*, 340 Scott St., Baltimore 3, Md.

Gentlemen: Send me a Fast's Catalog giving detailed descriptions, engineering drawings, capacity tables and photographs.

Name..

Company..

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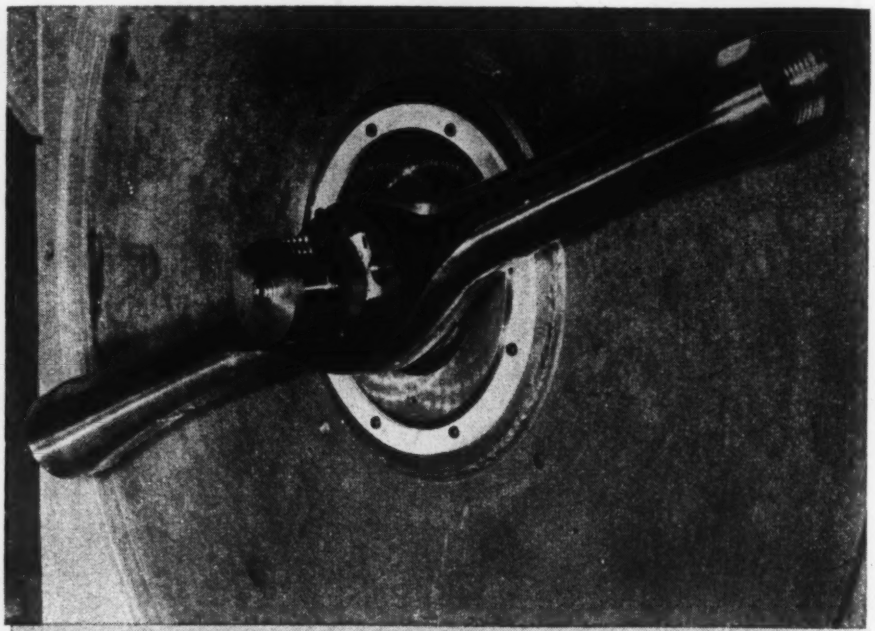
useful where it is subjected to high demagnetizing fields. In high-frequency applications, Cromag shows a very low loss and minimum proximity effect on associated circuitry.

The new material is a powder that is fabricated by powder metallurgy methods adaptable to pressing in a wide variety of intricate shapes without machining. It can also be supplied in long rods, tubes, square, rectangular or other symmetrical shapes.



HIGH-*G* CENTRIFUGE: An 8-cylinder, 160-horsepower automobile engine working through a step-up gear box drives this 37-inch centrifuge arm at 11,000 rpm to produce accelerations as high as 60,000*g* on a 1-pound specimen at the National Bureau of Standards. At the 11,000 rpm speed, specimens have a velocity of about 1200 mph, and the force at the hub section is in excess of 830,000 pounds

Robot System Monitors Bearing Temperatures

An automatic electronic temperature monitoring system, developed for the U. S. Navy, is expected to eliminate engine shutdowns due to bearing "burnouts." Excessive bearing temperature will automatically sound an alarm and cause a light on an instrument panel to glow, thereby pinpointing the hot bearing and allowing corrective measures to be taken.

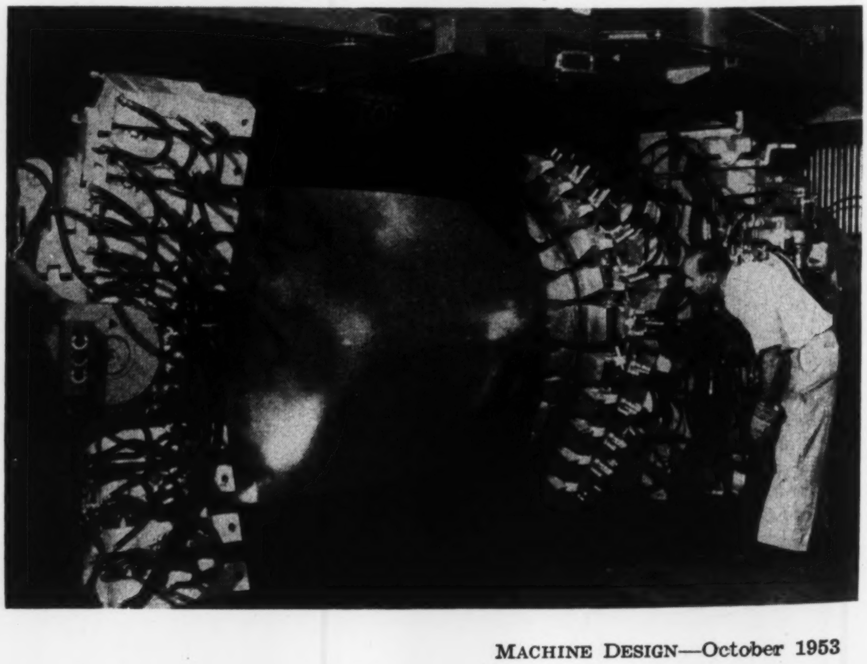
Heart of the system, developed by the Industrial Div. of Minneapolis-Honeywell Regulator Co., is an electronic scanning instrument capable of checking temperatures in 40 locations in 10 seconds. In operation, as many as 40 thermocouples are embedded in as many bearings; the scanner automatically checks each temperature six times per minute. High bearing temperature will sound the alarm and the attendant seaman determines exact location of the hot bearing by turning a selector switch.

Flexible Jaws Facilitate Stretch-Forming

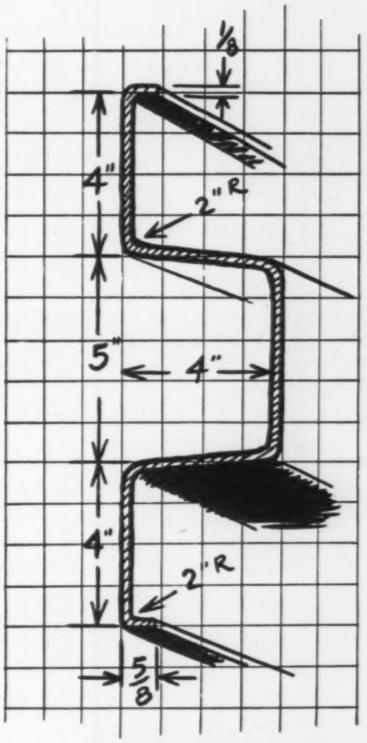
Composed of numerous segments, each containing a set of hydraulically actuated grippers, new flexible sheet-metal jaws hold the work sheet in a curved position during stretch-forming operations. The Hydra-Curve jaws, made by the Hufford Machine Works Inc., are said to simplify formation of parts with less wrinkling and permit forming of exceedingly deep curves. As much as 30 per cent of the material normally allowed beyond the ends of the die for transition stresses when using straight jaws may be saved because transitional stresses are largely eliminated by the curved jaws.

Jaw segments are hinged to each other permitting a wide variety of curves to be formed—half round, "S", concave, convex and others. Degree of curvature is established

Part being stretch-wrap formed over a non-symmetrical die. One jaw is convex while the other is concave



Many a New Cold-Formed Shape Starts with a Customer's Idea



Often an inquiry and a rough pencil sketch submitted by a manufacturer lead to two things: (1) a new, cost-cutting application for Bethlehem Cold-Formed Shapes, and (2) a satisfied customer.

Lately we've formed and, in some instances, fabricated shapes for such diverse uses as door tracks, radiant baseboard sections, parts for engine containers, hatch covers for sea-going vessels, and cold-formed storage racks. Ideas for these applications came from our customers.

Bethlehem Cold-Formed Shapes are regular or irregular shapes formed cold from strip, sheet or plate steel. They are uniform in thickness, with a surface relatively free from scale. They have a high strength-to-weight ratio. We make them on presses, brakes or rolls in all gages from 5 to 24, and in virtually any length.

In analyzing your shop operations, perhaps you'll find a new use for Cold-Formed Shapes. Our engineers have the skill and experience to turn your idea into a practical and economical product.

Ask the nearest Bethlehem sales office for a copy of our booklet on Bethlehem Cold-Formed Shapes.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM
STEEL

S-curves are possible with segmental Hydra-Curve jaws for stretch-wrap forming of sheet metal

by adjustable set-screws acting as stops in front of as well as behind each segment. One set of stops holds the jaws straight for loading; the other set controls desired curvature, allowing loading of flat sheets and curving the sheet just before or during the stretch-forming operation. Graduations on the set-screw stops permit recording and easy duplication of set-ups for reruns.

High-speed photography and time-lapse photography are now being offered as a field service by Sam Tour & Co. Inc., industrial consulting firm. High-speed motion pictures can "slow down" time so that an action normally occurring in one second can be viewed as a slow-motion sequence lasting three minutes. Time-lapse photography might be described as the opposite of high-speed photography allowing processes which occur very slowly to be viewed as a fairly rapid sequence of events.

Hard Coating Available for Aluminum

First commercial license for the Martin Hard Coating Process has been issued to Anodic Inc. by the Aluminum Co. of America. Aluminum coated by the process has a hard surface, usually 0.002-inches thick. High abrasion and corrosion resistance, low coefficient of friction and high dielectric strength are claimed to be other properties of the coating.

The process is a special anodic treatment which creates an amorphous coat of aluminum oxide about ten times thicker and 30 to 100 per cent harder than convential anodizing processes. The coating grows equally above and below the surface of the original aluminum part so that the normal 0.002-inch thick coating actually increases thickness 0.001-inch on a surface or 0.002-inch on a diameter. Coating buildup can be controlled within very close tolerances and can be as thick as 0.008-inch for salvaging undersize parts.

PROD. ENG
MACHINE DESIGN

"And then when we idle it down she sounds like this—"

The **Western Electronic Show and Convention,** held in the San Francisco civic auditorium August 19-21, registered nearly 14,000 engineers, scientists and technicians. Technical sessions were attended by 1500 while 12,500 visited displays of 370 exhibitors. Cosponsors are the Seventh Region Institute of Radio Engineers and the West Coast Electronic Manufacturers' Association.

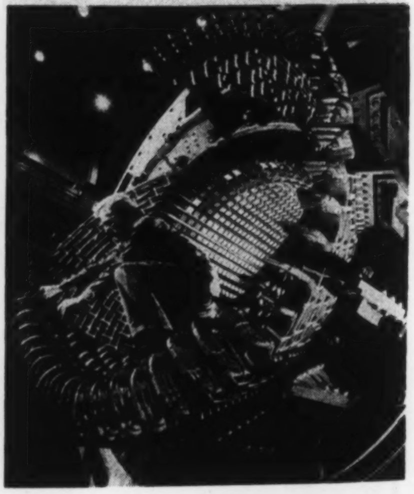
On view for the first time was a new exhibit of Western historical electroniana, including early electron tubes and communication equipment. A continuing function, this collection will be housed between shows at the Menlo Park headquarters of Stanford Research Institute.

Strain Gages Provide Overload Protection

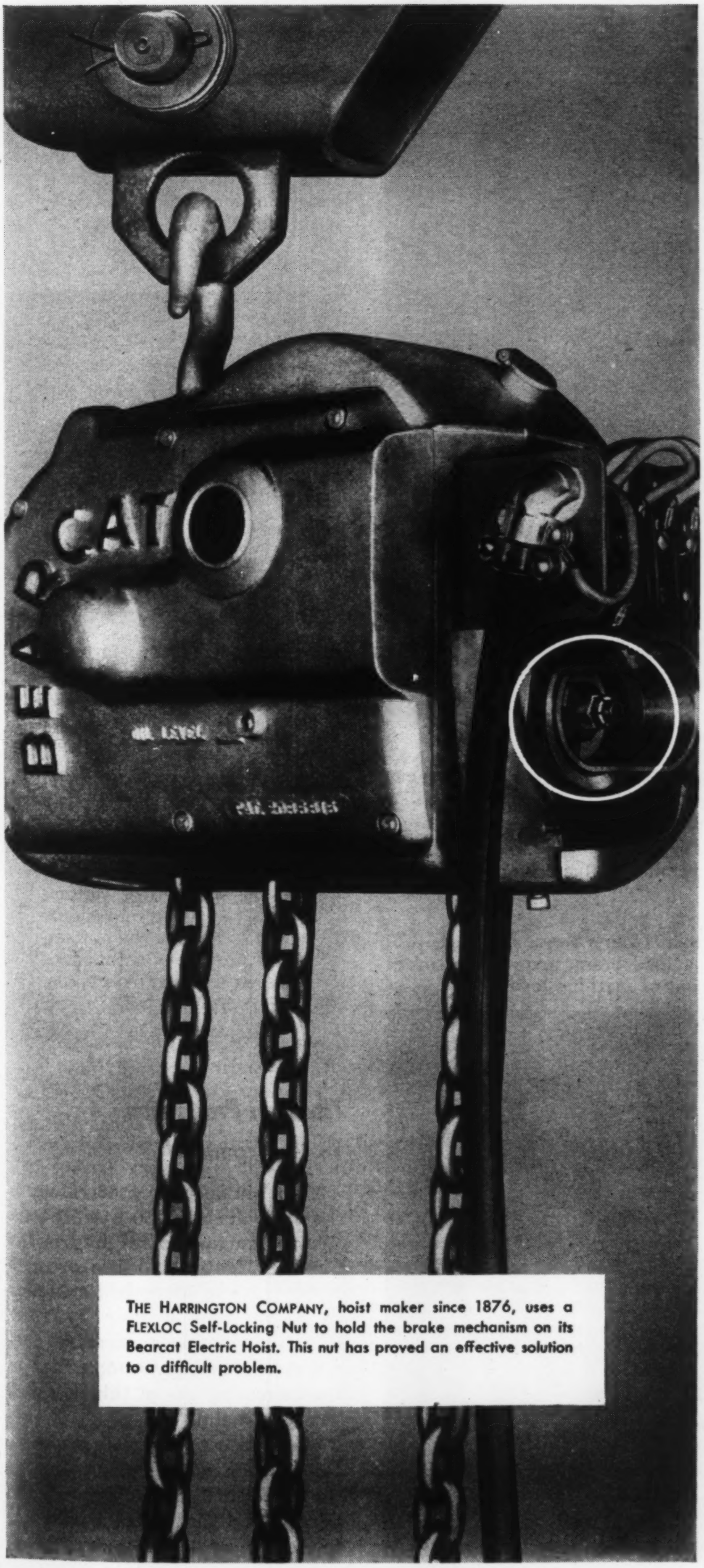
Centrifuges used in the manufacture of polyvinyl chloride resin powders are now being protected from overloads by a highly sensitive load sensing device or load beam employing strain gages.

Torque to operate the centrifuge is transmitted to a shear pin in a sleeve mounted on a pinion shaft and extending horizontally from the driving gear unit on the end of the centrifuge, as shown. The shear pin is kept from turning by a holder from which a rod extends down through a clevis where it is retained by a clevis pin. The clevis is attached to the end of the load beam, which is supported by a bracket extending from the base of the centrifuge.

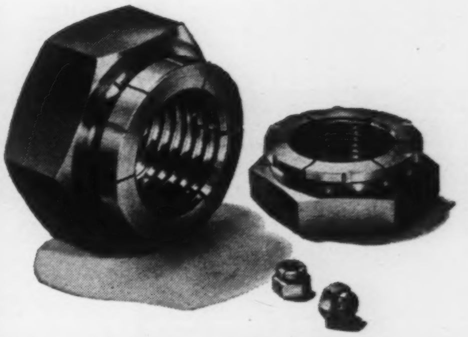
Deflection of the rod due to



GIANT GENERATOR: Insulating tape is being applied here to the coil ends of the stator of a 135,000-kw turbine-generator. The giant Westinghouse made machine will be hydrogen cooled and supply enough power to meet the needs of a city of 270,000



THE HARRINGTON COMPANY, hoist maker since 1876, uses a FLEXLOC Self-Locking Nut to hold the brake mechanism on its Bearcat Electric Hoist. This nut has proved an effective solution to a difficult problem.



Why FLEXLOCs are better locknuts

Compare the features of FLEXLOCS with those of any other nut, and you'll readily see why we say they are better locknuts.

FLEXLOCS are one piece, all metal. They require no lockwasher, no cotter pin, no auxiliary locking device to keep them on a bolt. They are not affected by moisture, dust or high temperatures. Standard FLEXLOCS are designed for temperatures up to 550° F.

FLEXLOCS are stop and lock nuts. They won't work loose once their locking threads are fully engaged; therefore they stay put anywhere on a bolt. Seating is unnecessary. And FLEXLOCS can easily be removed from a bolt and reused again and again without losing their locking ability.

For more information about FLEXLOCS and samples for test purposes, see your FLEXLOC distributor, or write SPS, Jenkintown 18, Pa.

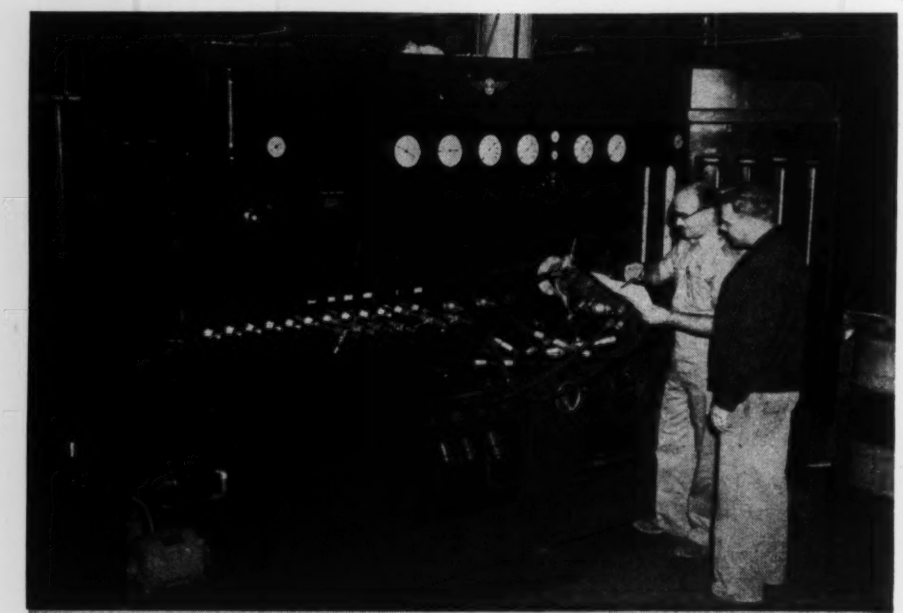
FLEXLOC®

LOCKNUT DIVISION

SPS

JENKINTOWN PENNSYLVANIA

Our Fiftieth Year : A START FOR THE FUTURE



PUMP TESTER: Actual operating conditions to evaluate pump performance are simulated by this lubricating oil pump test stand. Pump speeds, inlet and outlet oil pressures, oil temperature and flow rates can all be accurately controlled or measured. The stand is produced by Greer Hydraulics Inc.

torque developed in the gear unit subjects Baldwin SR-4 strain gages to compression on one side of the load beam and to tension on the other side. Changes in electrical resistance of the strain gages are transmitted to a recorder-controller and recorded on a chart. If the load exceeds a certain predetermined value, a lamp is lighted on an indicator panel to attract the attention of the operator who then reduces the feed rate to the centrifuge. If the torque increases at too great a rate and to a greatly excessive value, the drive motor is automatically shut off.

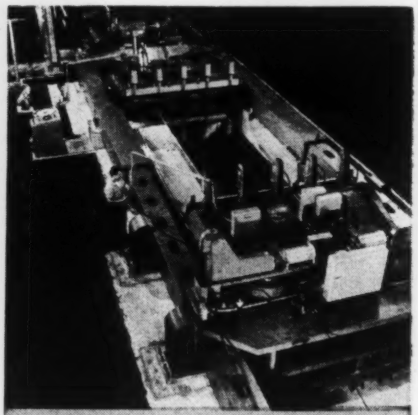
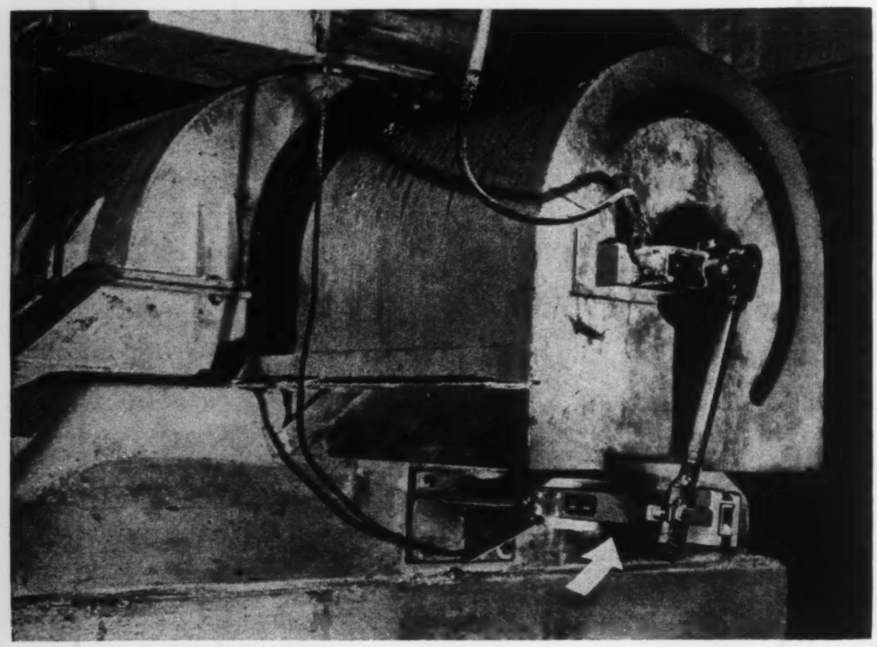


PLATE STRETCHER: Largest and most powerful in the world, this 5 million-pound plate stretcher can handle high-strength aluminum alloy plate up to 2 inches thick and 40 feet long. The stretcher is 81 feet long, 18 feet wide and 9 feet 2 inches high. Maximum stretch is 7 feet. Controlled stretching flattens plates, relieves residual stresses and develops uniform properties throughout plate at a Kaiser Aluminum rolling mill

Centrifuges separating polyvinyl chloride resins from a water slurry are protected against overloads by a Baldwin SR-4 load beam, arrow. A recorder provides continuous measurement of machine load



Titanium Production To Be Expanded

Total production of titanium in the U. S. during 1950 was 75 tons. Recent contracts made by the Defense Materials Procurement Agency are to increase production to 13,200 tons a year by 1956. This 1760 per cent increase over a 6-year period gives some idea of the increasing use of this so-called "wonder metal."

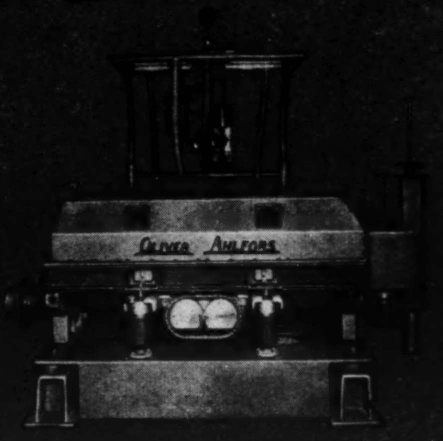
Most recent contract made by DMPA was with Cramet Inc., a wholly owned subsidiary of the Crane Co. The contract calls for production of 30,000 tons of titan-

PRODUCT DESIGN STUDIES • NO. 51

Screen frame of cast-weld construction

PULP SCREEN FRAME

Cast-Weld Assembly



View of complete screen*

Redesign to Cast-Weld Construction Cut cost 12%, increased durability

The pulp screen frame is part of the piece of equipment shown above used in paper mills for processing wood pulp.

Originally of bolted construction, the frame required expensive machine work and fastenings. Through cooperation of the manufacturer's engineering department and the steel foundry the frame was redesigned to cast-weld construction.

Conversion to cast-weld construction reduced the cost of the frame 12% and made it stronger—advantages which benefited both the manufacturer and his customers.

* * *

Here is another example of the foundry cooperation which is resulting in lower costs and improved products through redesign to steel castings.

This service is offered without cost or obligation. It makes available through your foundry representative the full results of the development and research program carried on by the Steel Founders' Society of America.

*Oliver-Ahlfors Upflow Vibratory Pulp Screen

51 YEARS OF SERVICE TO INDUSTRY

STEEL FOUNDERS' SOCIETY OF AMERICA
920 Midland Building
Cleveland 15, Ohio

Design and Build With Steel Castings

ium sponge, the almost pure material from which titanium is made, over a 5-year period. DMPA has similar contracts with Titanium Metals Corp. of America and E. I. Du Pont de Nemours and Co.

DESIGN
ENGINEERING
DEPT.
MACHINE DESIGN
Glueck

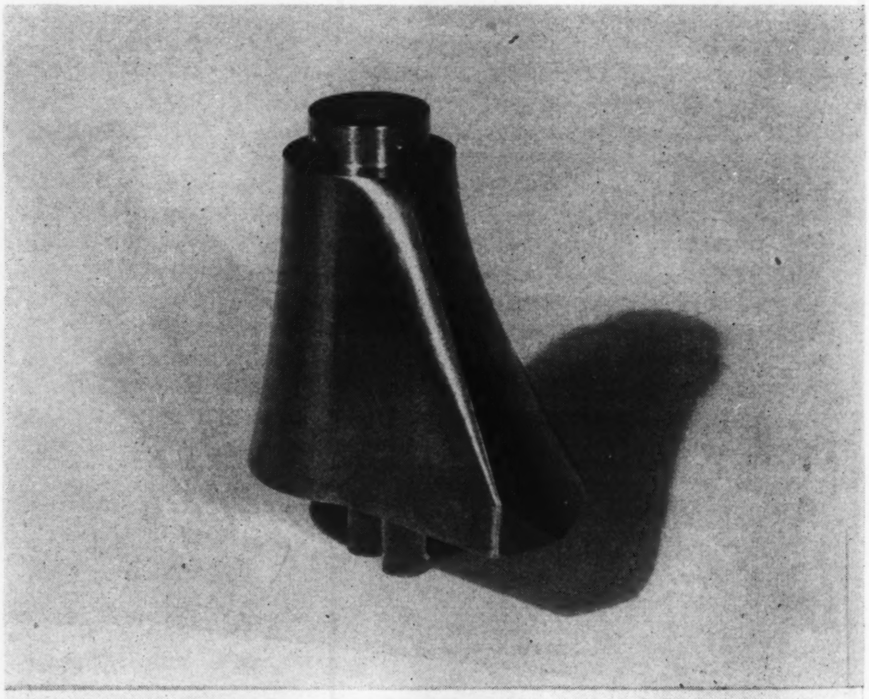
"Must be terribly hush, hush—"

Construction of a new plant to adjoin Eutectic Welding Co.'s present plant has begun in Flushing, N. Y. At the North end of the 273 foot building raw materials will enter the mechanized production line; at the South end the finished products will be carried on a conveyor due East to the Shipping depart-

The largest press ever used in electrode manufacture in New York will be installed. The building is so designed that it can be isolated completely from the remainder of the plant, should Government work necessitate complete secrecy.

High Loads Accurately Measured

Accurate measurement of forces up to 12 million pounds is possible with four 3-million pound compression dynamometers recently completed at the National Bureau of Standards. Prior to development of these dynamometers, which use strain gages as part of their load indicating systems, the highest load which could be accurately measured was 2½ million pounds. It is estimated that a testing machine can now be calibrated to 10 million pounds using the new dynamometers in one-fourth the time and at half the cost previously required to calibrate to 2½ million pounds.

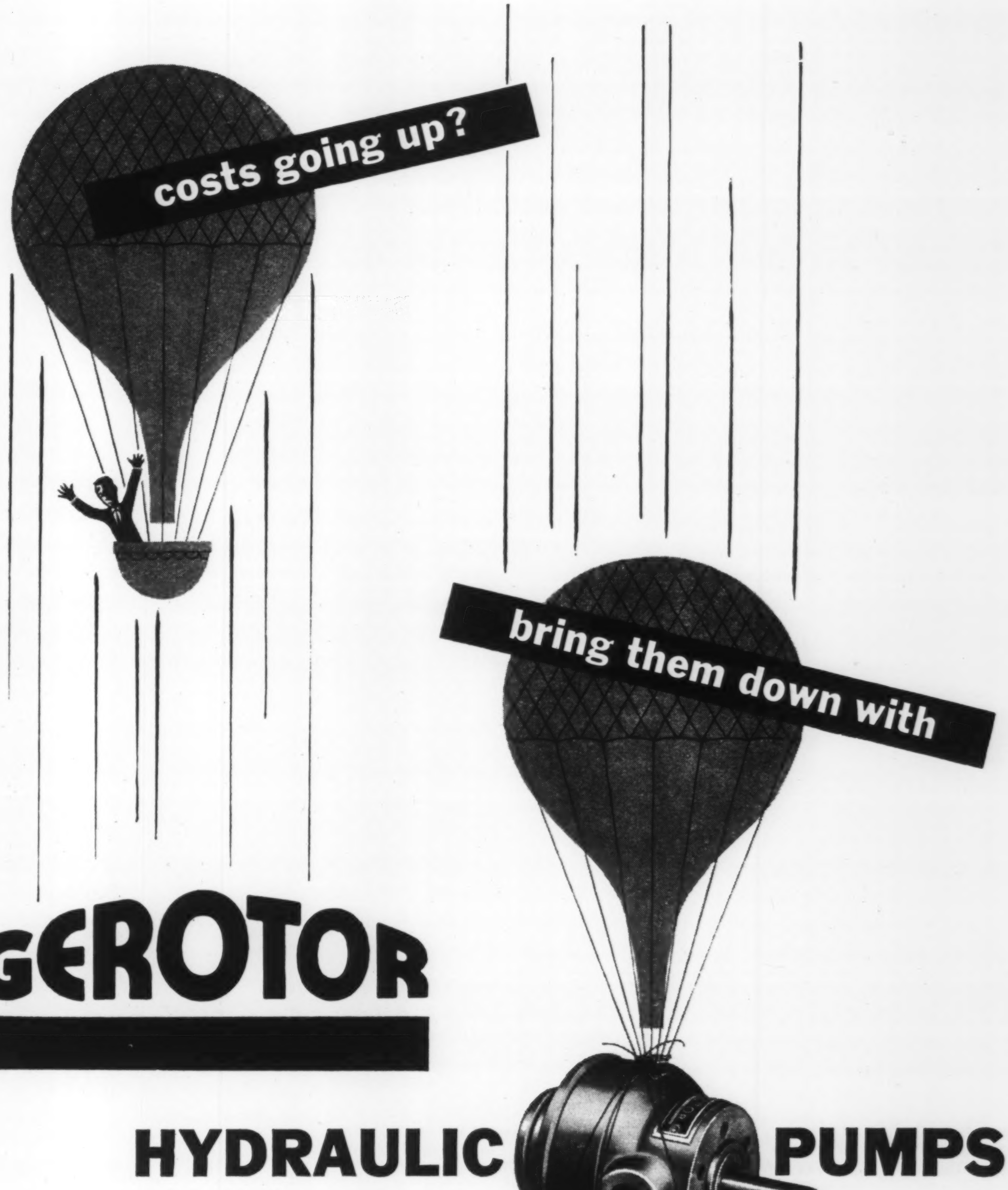


THREE-D CAM: Many mechanical and electrical devices in a group of highly complicated computing mechanisms being built for the Air Force process their data through the three-dimensional cam shown. High accuracy in such an application is essential. To be certain of the required accuracy, as many as 2000 data points are end-milled on a hand-cut master cam controlling pantograph-type cam cutting machines at the Ford Instrument Co. Cams are cut to tolerances of ±0.0005-inch and then hand polished to produce a 20 micro inch finish

The **First International Machine Tool Exposition,** an international showcase for the metal-working industries, opened in Brooklyn on October 5. Designed to fill the need for a permanent center to display American and foreign machine tools, the exposition will keep manufacturers up-to-date on the latest developments and methods of the machine tool industry. Sponsored by S & S Machinery Co., the exposition marks the first time in industrial history that such an assemblage of machine tools—approximately 1000—has been permanently exhibited.

Mass production of titanium tubing in sizes from 0.125 to 1.500 inches in outside diameter and from 0.004 to 0.187-inches in wall thickness has been achieved. High temperature and corrosion resistance of titanium have created a demand for the tubing in many applications.

A newly installed vacuum annealing furnace at the Superior Tube Co. makes production of the tubing in lengths to 24 feet possible. The furnace is also used for the annealing of zirconium tubing; however, availability of zirconium metal is such that only small experimental quantities of the tubing are available.



GEROTOR

HYDRAULIC PUMPS

A well-designed hydraulic circuit can help bring soaring costs down to earth . . . in your product, in your plant. The best-designed hydraulic circuits are built around Gerotor pumps . . . for high efficiency, longer life, less slippage, more uniform flow. Engineered for pressures up to 1000 p.s.i. continuous duty; in some sizes, up to 1200 p.s.i. continuous, 1500 intermittent. Deliveries from .4 g.p.m. at 1800 r.p.m. to 40 at 1200 r.p.m. Specify Gerotor!

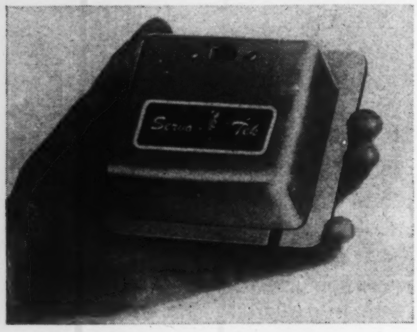
GEROTOR MAY CORP., BOX 86, BALTIMORE 3, MARYLAND

NEW PARTS AND MATERIALS

For additional information on these new developments, see Page 257

Electronic Relay

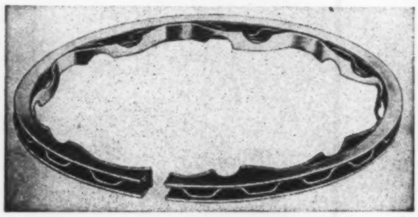
Action can be initiated by external contact as high as ½-megohm with current as low as 0.0001-amp. Features include a simplified circuit, silver relay contacts and a cold cathode tube. Contact rating is 4 amp, with a choice of normally open, normally closed or single-pole, double-throw contacts. Mounting on a standard 4-in. electrical connector box, the relay requires 115-v, 25 to 60-cycle, single phase power. Made by **Servo-Tek Products Co. Inc.**, 1086 Goffle Rd., Hawthorne, N. J.



For more data circle MD-64, Page 257

Piston Ring

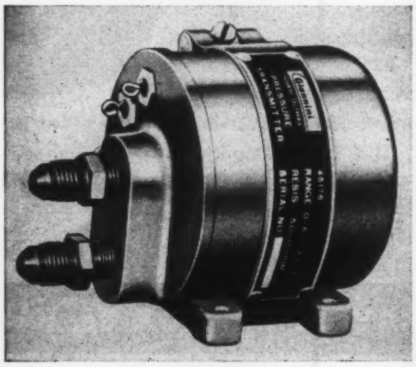
The multiple-piece, chrome plated Unitized CSR-200 oil control ring comes preassembled and bonded together with an adhesive agent that dissolves in the heated engine oil during run-in. The all steel ring reduces scuffing, ring wear, bore wear and friction. Made by **Muskegon Piston Ring Co.**, Sixth and Alpha Sts., Muskegon, Mich.



For more data circle MD-65, Page 257

Pressure Transducer

Adaptable to many uses in industrial, missile or aircraft applications, model 45176 pressure transducer can also be used as an altimeter and for air speed pressure or ram pressure measurement. Up to 50 v output can be obtained where an electrical signal proportional to pressure is required. Construction details include stable insulating materials such as glass, frictionless spring flexure pivot movement, and static and dynamic balancing. Weight is under 14 oz.

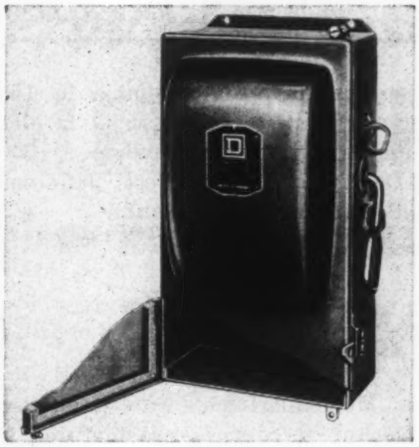


Output is linear with applied pressure, but linear outputs can also be supplied with altitude, air speed, or to natural or empirical functions. Dual outputs can also be provided, independent if desired. Ranges from 0-10 to 0-30 psi in 5 psi increments are available in special pressure ranges. Unit will operate when subjected to environmental vibrations of 5*g* in frequency range from 10-500 cps and can be made to withstand shocks of 40*g* without damage. Made by **G. M. Giannini & Co. Inc.**, 117 E. Colorado St., P. O. Box N, Pasadena 1, Calif.

For more data circle MD-66, Page 257

Safety Switches

Produced in 30, 60, 100 and 200 amp ratings for either 240 v ac or 250 v dc and 600 v ac/dc service, NEMA XII safety switches are designed for the machine tool and processing industries as well as industrial plants requiring a switch enclosure which will exclude dust, dirt, oil and coolants. Heavy steel box cover is sealed by a neoprene gasket (shown inset) and is closed by latch and captive screws. Cover and operating mechanism are interlocked, and no conduit openings or knockouts are provided, each installation being "tailor-made." Switch and mechanism are of heavy-duty visible blade type with magnetic blowout plates, nontrack-



ing insulation, silver plated copper parts and pressure fuse clips. Made by **Square D. Co.,** 6060 Rivard St., Detroit 11, Mich.

For more data circle MD-67, Page 257

Cushioned Clamps

Series TA1716 and TA1774 stainless steel clamps resist temperatures to 1200 F. The cushioning material, spun glass, is wrapped around the clamps which are then dipped in an aluminum and silicate base paint for a binder. Available in sizes from ⅛ to 6 in. in diameter, in 1/16-in. increments in single and multiple tube clamps from **Thomas Associates,** 4607 Alger St., Los Angeles 39, Calif.

For more data circle MD-68, Page 257

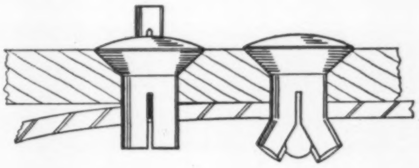
Rod Packings

Impregnated with 35 per cent Teflon, braided asbestos rod packings show high resistance to acids and alkalies, and withstand temperatures ranging from −90 to 500 F. Two types are available, white asbestos for dilute acids, caustics and various chemicals on centrifugal or reciprocating pumps and valve stems, and blue for use on similar installations handling more highly concentrated acids and chemicals. Made by **United States Rubber Co.,** Rockefeller Center, New York 20, N. Y.

For more data circle MD-69, Page 257

Blind Rivet

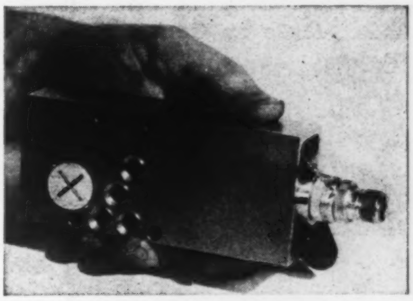
This oval head countersunk drive rivet is useful as a blind fastening for wood and metal where a finished head appearance is of importance. It can be applied from one side of the work at high speeds, and exerts a strong pulling-together force on the parts. It can be installed with an ordinary hammer, expanding the four prongs against the interior surface. Rivet is available in diameters of ⅛, 3/16 and ¼-in.; grip lengths vary from 3/32 to ⅝-in. Made by Southco Div., **South Chester Corp.,** Lester, Pa.



For more data circle MD-70, Page 257

Hydraulic Servo Valve

This low-leakage, self-clearing valve is a two-stage, four-way model with internal mechanical feedback for transforming low-level electrical information into controlled hydraulic energy. Sealed against magnetic particles, it can be operated without oil filters, and exerts a force of up to 500 lb in the first stage to remove sludge, dirt or metal particles. Frequency response is flat from 0 to 150 cycles per second. The valve has a linear output up to 14 hp, with no external leakage and a zero signal leakage of only 60 cu cm per minute. Power amplification is 5000 with pressures up to 3000 psi. Input power is less than 2 w; input current, 15 ma. Resolution is 0.03 per cent; time constant, 0.001 seconds. The valve measures 1 5/16 by 2 7/16 by 5½ in. with a volume of less than 18 cu in. and has a flow of up to 12 gpm. It weighs under 1¾ lb. Life expectancy is at least 4 million cycles. Made by **Sanders Associates Inc.,** Nashua, N. H.



For more data circle MD-71, Page 257

Miniature Accelerometer

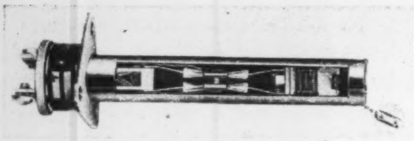
Available in ranges from $\pm 5g$ to $\pm 30g$, with corresponding natural frequencies from 25 to 50 cycles per second, this instrument measures 1⅛ by 1⅛ by 3 1/16 in. and weighs 6 oz. The pickoff element is a precision linear potentiometer with platinum alloy resistance winding and brush. Linearity is within ±1 per cent of full scale, and electrical centering of the potentiometer at zero input is within ±0.5 per cent. Standard potentiometer resistance is 10,000 ohms with an output resolution of 0.33 per cent and a continuous duty rating of 40 v. The hermetically sealed accelerometer operates in a temperature range of −60 to 180 F; withstands vibration of $10g$ from 10 to 500 cycles per second. It operates under $40g$ acceleration in any nonsensitive axis and 100

per cent overload on the sensitive axis, and 50*g* shock on any nonsensitive axis and 100 per cent shock overload on the sensitive axis. Made by **Genisco Inc.,** 2233 Federal Ave., Los Angeles 64, Calif.

For more data circle MD-72, Page 257

Thermostat

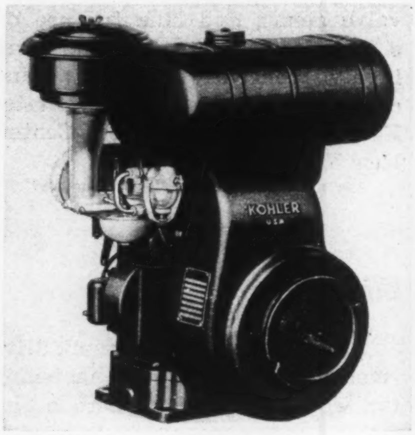
When used in any type of heating system, this unit controls the rate of heat output during the warm-up period and aids in bringing the system up to the desired temperature without overshoot. It also finds use in monitoring processes in which rate of heating must be controlled or in which temperature overshoots from a rapid heating cycle must be prevented. It may be used either with standard temperature controls or as a separate safety control. The Thermoswitch adjusts to control any heating rate between 10 and 100 F per minute and can be used at ambient temperatures from −100 to 550 F. It has excellent shock and vibration resistance and is hermetically sealed for protection against dust, grease, water or oil vapors. Rating is 5 amp at 115 v ac or 2 amp at 28 v dc. The unit is 4¾ in. long overall, ⅝-in. in diameter and weighs less than ¼-lb. Made by **Fenwal Inc.,** Ashland, Mass.



For more data circle MD-73, Page 257

Gasoline Engine

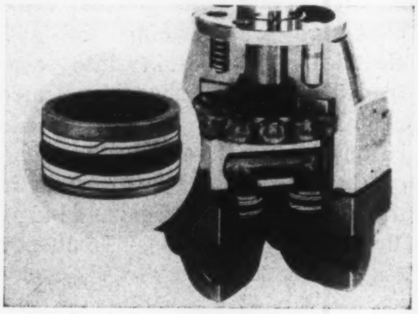
Delivering 6.6 hp at 3600 rpm, model K160 aircooled stationary gasoline engine weighs 67 lb and is a four-cycle single-cylinder type. It is equipped with oil bath air cleaner, ball bearings, silencer muffler, fly-ball governor and a 1¼-gal fuel tank. Three alternatives are available, one with a direct-mounting crankcase, one with a 6 to 1 reduction gear and the other with a hand clutch. Contact breaker points are readily accessible, and the breaker itself is resistant to dust and moisture. A stop button is mounted on its cover. Made by **Kohler Co.,** Kohler, Wis.



For more data circle MD-74, Page 257

Spiral Back-Up Rings

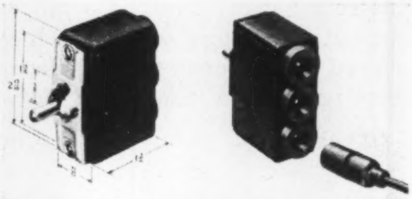
Rubber O-ring seals can be indefinitely protected against extrusion, deterioration or loss of efficiency by the SR series of Kelon-T (Teflon) spiral back-up rings. Available with chamfered ends, the chemically inert spiral packings will not swell, shrink, harden or soften and are unaffected by acids, oils, or bases or solvents. Usable temperature range is from −110 to 300 F. In some applications the back-up rings can seal without O-rings if the packing completely fills the groove in one continuous spiral of several layers. Available in 153 sizes from 0.125 to 15.50 in. ID. Made by **W. S. Shamban & Co.,** Dept. L, 11617 West Jefferson Blvd., Culver City, Calif.



For more data circle MD-75, Page 257

Toggle Switches

Molded-in female waterproof connector receptacles are featured in two series of waterproof toggle switches, designed for assembly with male waterproof plugs. All metal parts are plated for corrosion resistance. Switches are 100 per cent waterproof, meet government specifications, operate from −65 to 160 F and withstand severe shock and vibration. Series 29-ACM is a flush mounting switch, with capacities on resistive load of 25 amp at 24 v dc and 15 amp at 125 v ac. Series 19-ACM is one hole mounted and has a capacity of 25 amp at 24 v dc and 11 amp at 125 v ac. Each is offered as single pole-single throw or single pole-double throw, in eight toggle arrangements, with or without a center "off" position. Made by **Riverside Mfg. & Electrical Supply Co.,** 10228 Michigan Ave., Dearborn, Mich.



For more data circle MD-76, Page 257

Contact Material

Heat and pressure-laminated in ingot form and then cold rolled to required dimensions, Raised-Lay contact material consists of one or more ingots of precious metal bonded to a base metal. The base metal in strip form and the contacts in the form of a ridge or bar can be laminated into any strip width or thickness. Bonds are made in single, double or double-double com-

Proved! **by thousands of hours...on thousands of machines!**

ALEMITE OIL-MIST LUBRICATION

the most efficient lubricating system ever devised!

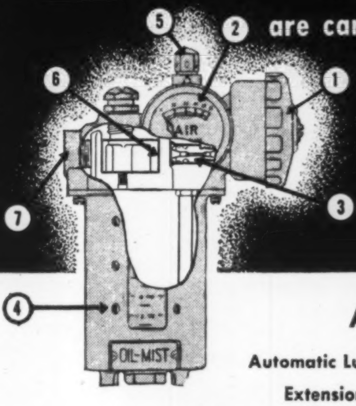
AIR
ALEMITE
12 OZ
10 OZ
8 OZ
6 OZ
4 OZ
2 OZ
OIL-MIST

1. MULTIPLIES Bearing Life!
2. CUTS Product Spoilage!
3. BOOSTS Machine Output!

Millions of actual machine hours on countless installations prove Alemite Oil-Mist is the most efficient automatic lubrication system you can specify. Easy to incorporate into new projects . . . just as easy to use in modifying existing designs! Oil-Mist can bring impressive savings in man-hours, bearing life, lubricant, decreased product spoilage . . . can save its cost over and over again!

This is an amazingly simple system of lubrication, which applies a clean, cool, constant and uniform film of oil wherever it is needed—to groups of bearings, slides, chains, gears—to any moving part. Oil-Mist is unique. The lubricator has no moving parts, operates on compressed air, and is completely automatic—proved completely foolproof.

HOW IT WORKS: **The Oil-Mist Lubricator atomizes oil into microscopic particles which are carried in the air stream and distributed through tubing to bearings**

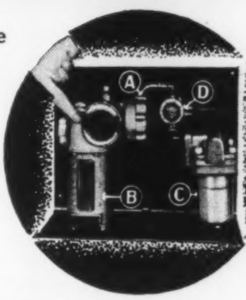


Oil-Mist airborne lubrication is accomplished this way: Compressed air entering the unit passes through air regulator (1) and air gauge (2). As this air passes through venturi (3) it draws oil from reservoir (4). Oil flow is set by knob (5). The mixture of air and oil from the venturi is thrust against baffle (6). Only the most minute, lighter-than-air particles are blown through outlet (7) into delivery line to lubricate bearings.

Alemite Oil-Mist offers all these lubrication advantages

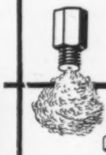
Automatic Lubrication • Continuous Lubrication • Eliminates Guesswork • Cuts Oil Consumption up to 90%
Extension of Bearing Life • Stops Oil Drippage • Reduction of Bearing Temperatures • Greater Safety
Reduction in Number of Lubricants • Protection from Contamination • Elimination of "Down-Time" • Manpower Savings

LUBRICATOR SPECIFICATIONS:

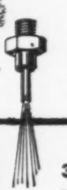


- Oil-Mist outlet ½" fem. p.t. Air gauge registers to 50 psi. Operating air pressure—5 to 20 psi.
- Air regulator **(A)** reduces from pressures up to 200 psi. Normal air consumption—.7 to 1.2 cfm.
- Range of oils handled—to 1,000 sec. (S.U.V.) @ 100°F.
- Oil reservoir **(B)** capacity 12 oz. (approximately 1 week supply). Intake filter screen—70 mesh. Fill plug—⁹⁄₁₆".
- Material—die cast aluminum body with nylon plastic window.
- Baffle-type water separator **(C)**—automatic self-dumping. Requires no manual attention—no filter elements to replace. Air inlet ¼" fem. p.t.
- Solenoid Control **(D)** starts system automatically when machine starts—foolproof.

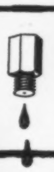
delivers oil to bearings *3ways*



1. Oil-Mist as Such. Most commonly applied to any type of anti-friction bearing—ball, roller or needle.



2. Oil in Spray Form. For open and enclosed gears and chains. Nozzle partially condenses mist so that it can be directed on to a concentrated area.



3. Oil-Mist Condensed. For plain bearings, slides, ways, vees, cams and rollers. In these applications, condensing fittings convert oil-mist to liquid oil.

A PRODUCT OF
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STEWART WARNER

Write Today! **This Oil-Mist Catalog and Engineering Data Book is FREE for the asking. Write now for your copy. Alemite, Dept. R103, 1850 Diversey Parkway, Chicago 14, Illinois.**

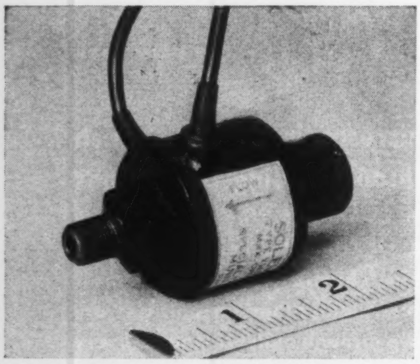
Alemite OIL-MIST Lubrication

binations. Wearing surfaces are rolled to required tempers for long service life. Made by D. E. Makepeace Co., Div. of **Union Plate and Wire Co.,** Attleboro, Mass.

For more data circle MD-77, Page 257

Solenoid Valve

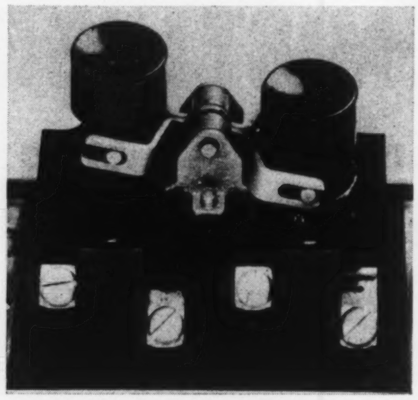
Major parts of this 5-oz valve are made of stainless steel, silver brazed for rigidity. It has no gaskets. A floating synthetic rubber needle valve insures positive closing at zero pressure. Standard models have 1/16-in. orifice. Valve can operate up to 1000 cycles per minute at pressures to 200 psi. Flow is straight-through. Voltages offered are 6, 12 and 24 v dc and 100 v ac, with special voltages on request. Made by **Specialty Products Co. Inc.,** 3725 Monitor Ave., Minneapolis 16, Minn.



For more data circle MD-78, Page 257

Heavy-Duty Pushbutton

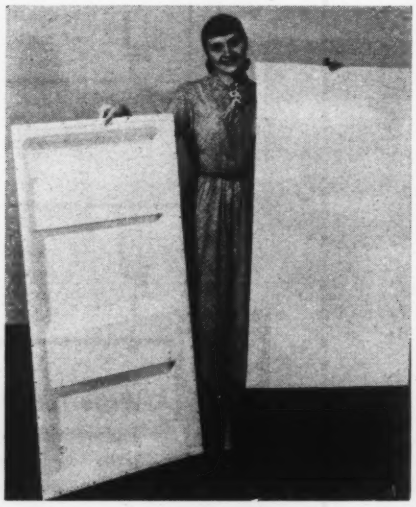
Consisting of two 2-point units, each with one normally open and one normally closed contact, this pushbutton is permanently assembled. Continuous and interrupting current ratings are: 10 amp continuous, 50 amp maximum interrupting at 110 v ac and 2 amp maximum interrupting at 125 v dc. It can also be used for 3 or 2-point applications. Positive action is achieved by the use of a snap-action over-center toggle that mechanically interlocks the buttons. Size of the unit is approximately 3 by 3 by 4 in. Available in seven colors in open form or in a surface-mounted steel enclosure from **Westinghouse Electric Corp.,** P. O. Box 2099, Pittsburgh 30, Pa.



For more data circle MD-79, Page 257

Plastic Sheet Material

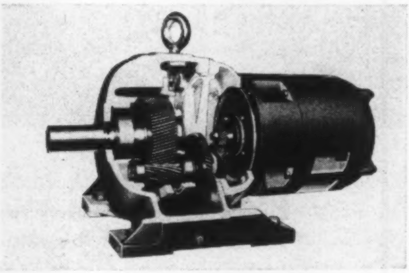
A copolymer of polystyrene and rubber, Campco S-300 is a rigid plastic sheet material available in any desired color in widths ranging from 26 to 58 in., and in thicknesses from 0.005 to 0.125-in. It is fabricated by extrusion through continuous equipment and has a smooth surface and a finish which can be regulated from matte through high gloss. It machines easily, has high impact strength and lends itself to the simple vacuum forming process. It is also light in weight, requires no expensive finishing operations, can be easily cleaned and is moisture-resistant. Illustrated is a refrigerator door liner which has been vacuum formed from a basic sheet such as that shown at the right. Other applications include ducting, interior roofing, paneling, tote boxes, wall tile, lighting fixtures, reflectors and illuminated signs. The material takes print and paint well and can be vacuum coated with aluminum or silver. Made by Campco Div., **Chicago Molded Products Corp.,** 2717 North Normandy Ave., Chicago 35, Ill.



For more data circle MD-80, Page 257

Gearmotors

Series of integral gearmotors in ratings from 1 to 15 hp are available in a wide range of speeds in single, double and triple gear reductions. Units meet AGMA class I, II and III specifications and fit varying load requirements. Motors can have constant or varying speeds and protective frames for operation under most atmospheric conditions. Made by **Century Electric Co.,** 1806 Pine St., St. Louis 3, Mo.



For more data circle MD-81, Page 257

Sealed Power Connectors

Manufactured to Signal Corps Specifications in the range from U-112/U to U-117/U, these connectors have 90-degree angle plugs with wing blade handles for easy engagement and disengagement. Receptacles are round, with a lock ring for panel mounting. Contact

Extra

dependability through extra value features...in Adlake Mercury Relays

Dependability is the sum of many things . . . and ADLAKE's dependability is built on a combination of plus features like these:

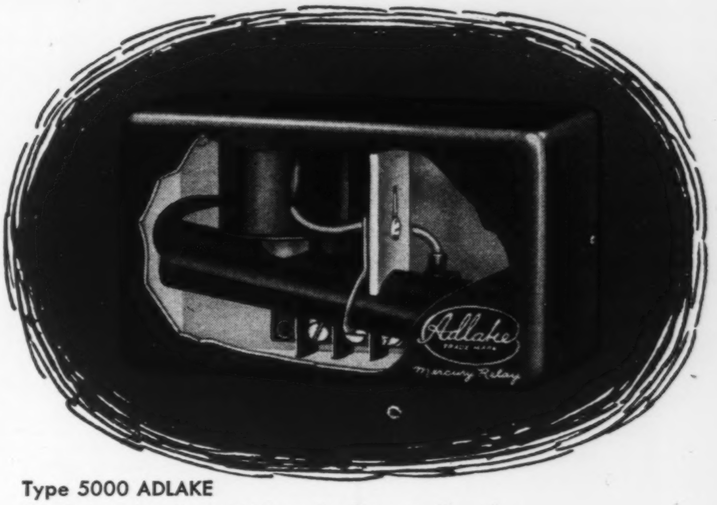
Positive leak-proof sealing—assured by the use of properly selected metals and glass components with properly matched thermal expansion characteristics.

Arc-resisting ceramics—ceramics with great temperature-resistance are used to reduce any destructive effect caused by the arc.

Liquid mercury-to-mercury contacts—completely eliminate failures caused by low contact pressure, contact burning, pitting and sticking . . . and the inherent high surface tension of mercury imparts an ideal snap action to contacts.

What's more, every ADLAKE Relay is absolutely safe . . . silent and chatterless . . . and requires no maintenance whatsoever. Get the complete story today . . . write for your free copy of the ADLAKE Relay Catalog. The Adams & Westlake Company, 1173 N. Michigan, Elkhart, Indiana; in Canada, write Powerlite Devices, Ltd., of Toronto.

Every ADLAKE Relay is tested
[illegible]
[illegible]



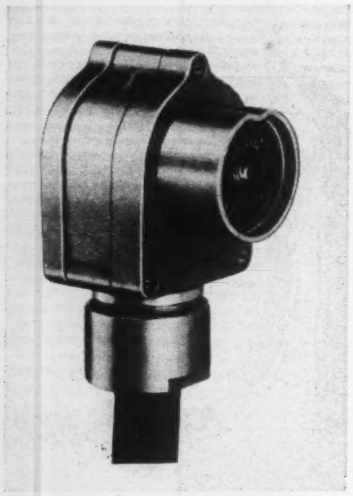
Type 5000 ADLAKE
Sensitive Relay Contact Normally Open or Closed

Adlake
TRADE MARK
96th year
of serving the transportation and building industries

THE
Adams & Westlake
COMPANY

Established 1857 • ELKHART, INDIANA • New York • Chicago
Manufacturers of ADLAKE Hermetically Sealed Mercury Relays

arrangements are 4-No. 16, 12-No. 16 and 29-No. 16 contacts having 2500 v ac rms flashover values.



Finished in cadmium plate and olive drab chromate, the connectors are waterproof and pressurized. Made by **Cannon Electric Co.**, 3209 Humboldt St., Los Angeles 31, Calif.

For more data circle MD-82, Page 257

Speed Reducers

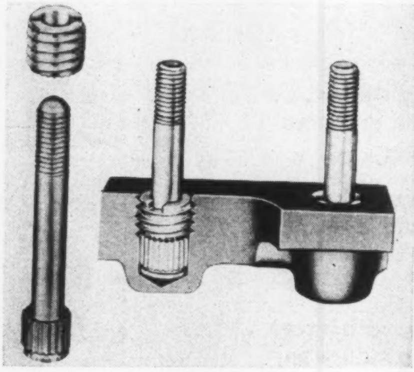
Streamlined housings of these units are dustproof and oil-tight, meeting rigid sanitary requirements. They are made with 1 to 8-in. centers, in 5.8:1 to 100:1 ratios and with top or bottom worms, single or double reduction. Shafts and bearings are designed for high overhung load capacities. Bearings are located close to the worm for minimum distortion and deflection. The units are also available with right angle vertical or parallel shafts in 1 to 8-in. centers, with top or bottom worms in 5.25:1 to 100:1 ratios. Right angle or parallel shaft gearmotors are available in a 1/50 to 40-hp range. Made by **Rynel Corp.**, Sterling, Ill.

For more data circle MD-83, Page 257

Threaded Stud

Provided with a positive lock against both rotation and pull-out, this threaded stud is available in cadmium plated alloy steels, stainless steels or special alloys for service with metal or plastic components. The stud itself has a knurled head which broaches its way into the component and prevents rotation, then the pressure ring is screwed into place, locking the stud against pulling out. This pressure ring can be used more than once, and installation and removal are simple. Illustration shows exploded, cut-away and installed views of the device, which is available from stock in standard stud sizes. Made by **Newton Insert Co.**, 1321 East Seventeenth St., Los Angeles 21, Calif.

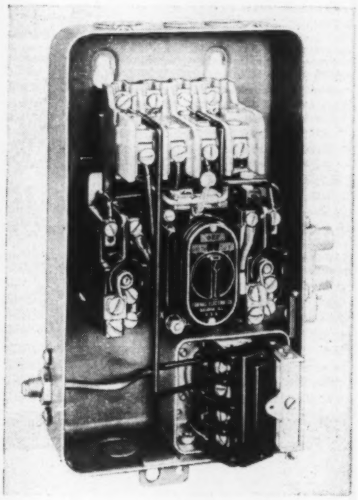
For more data circle MD-84, Page 257



Magnetic Starter

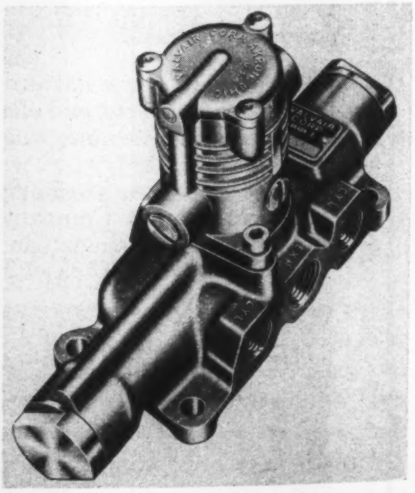
Designed for application on pumps and air compressors, this unit combines a starter, a pressure switch and an automatic unloader valve. Measuring 6 3/16 by 10¼ by 4 3/16 in., it mounts directly on the motor. Three sizes up to 5 hp at 220-550 v, single phase or 10 hp at 440-550 v polyphase are available. Series G pressure switch has a capacity of 80 lb; series H, 200 lb. Made by **Furnas Electric Co.**, 1000 McKee St., Batavia, Ill.

For more data circle MD-85, Page 257



Air Control Valves

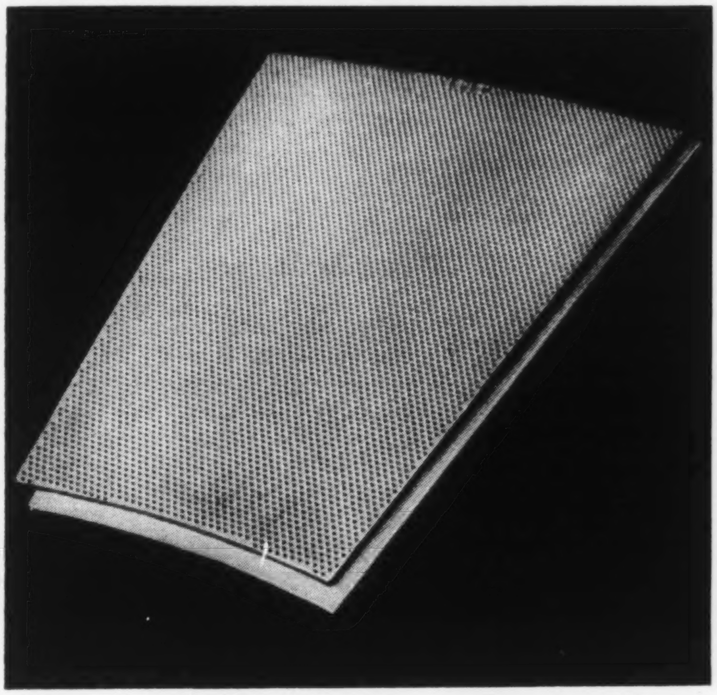
With an operating expectancy exceeding 20 million cycles, these solenoid pilot-operated valves are available for three-way, four-way, and four-way, five-port (two pressure) application in pipe sizes ¼ through 1 in. All are furnished for either foot or sub-base manifold mounting in accordance with J.I.C. specifications. All parts are



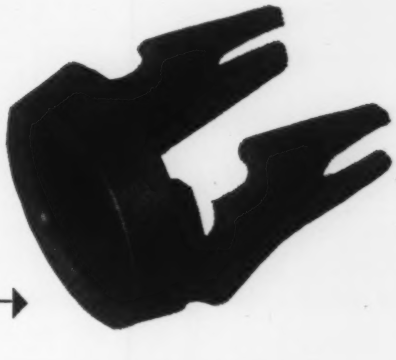
Now They Are Mass Produced

by HAYNES Investment Casting

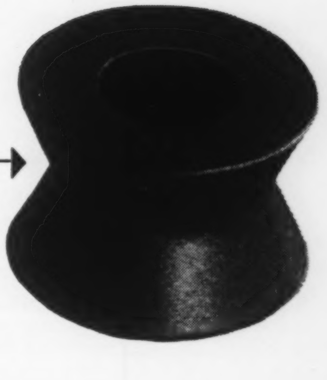
Trade-Mark



← **IMPROVED DESIGN AND MATERIAL**—The tiny needle-sharp points covering this plate must resist severe abrasion. Machined points used to wear out frequently because they were pyramidal in shape and highly susceptible to erosion. HAYNES investment casting made it possible to cast the points in a more stable conical shape from a hard, wear-resistant alloy. Life has been increased by 5 to 12 times.



EXCELLENT SURFACE QUALITY—For sanitary reasons, not even the smallest crevice can be tolerated on this cream separator part. Because of the high quality of HAYNES investment castings, it was found that the intricate part could be manufactured on a production basis with a minimum of imperfections showing up during the final polishing operations. This eliminated a great deal of wasted time, work, and metal. →



NO MORE MACHINING—HAYNES investment casting eliminated the job of machining these rollers. Service conditions require that the rollers be made of a special alloy which is difficult to machine. They must resist rusting and the cutting action of wire passing over them under tension. The rollers give excellent service life and there are no more machining problems. →

HAYNES investment castings can solve some of your own production and design problems. For more information, contact the nearest Haynes Stellite Company office listed below.

"Haynes" is a registered trade-mark of Union Carbide and Carbon Corporation.

HAYNES INVESTMENT CASTINGS

Trade-Mark

Sound, dense, high-strength parts available in cobalt-base alloys, nickel-base alloys, iron-base alloys, stainless steels, and alloy and carbon steels.

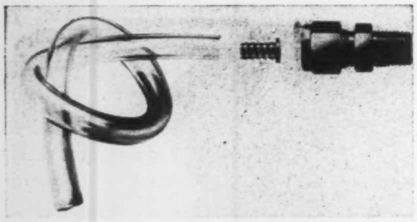
Haynes Stellite Company
A Division of
Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
Sales Offices
Chicago — Cleveland — Detroit — Houston
Los Angeles—New York—San Francisco—Tulsa

corrosion resistant. The main valve does not have a spring, since air from the pilot valve is utilized to reverse the spool in both directions. The spool is the only moving part of the main valve body. The pilot valve control unit is manifolded with cap screws to the main valve body. The replaceable solenoid coil is available for any ac voltage or frequency as well as for dc. Maximum current consumption at any voltage is 10 w. The valves are designed for 35 to 150 psi air pressure and low pressure hydraulic service. Manufactured by **Valvair Corp.**, 454 Morgan Ave., Akron 11, O.

For more data circle MD-86, Page 257

Plastic Tube Fittings

Now available in any metal, Swagelock plastic tube fittings and inserts are designed to furnish a positive seal and fast assembly. Inserts prevent cold flow in the tubing and support its inside dimension, providing the backing strength required by the tubing.

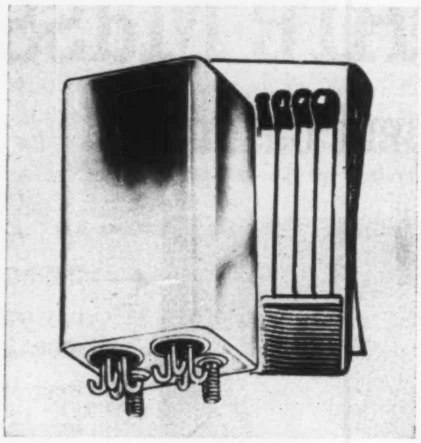


The insert is slipped into the end of the tube, and the fitting then pushed on and tightened 1¼ turns to complete the assembly. Inserts are available from 3/16-in. OD and up. Made by **Crawford Fitting Co.**, 884 E. 140th St., Cleveland 10, O.

For more data circle MD-87, Page 257

Miniature Relays

Suitable for commercial and military applications is this line of miniature relays, series 100-105-106, measuring 1 by 1 by 1¾ in. They are sensitive to low input, are hermetically sealed with headers for solder connections and have high shock immunity. Series is available either single-pole double-throw or double-pole, double-throw. Silver contacts are rated 2 amp at 28 v dc resistive. Made by **Signal Engineering & Mfg. Co.**, 154 West 14th St., New York 11, N. Y.

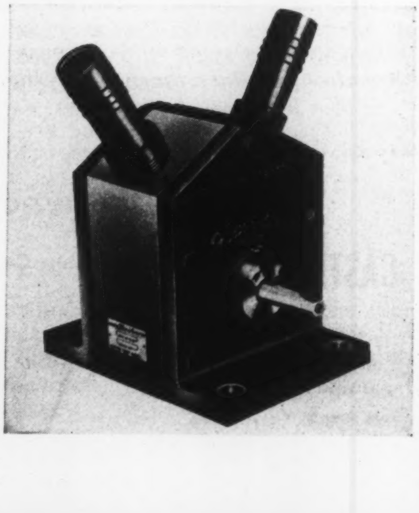


For more data circle MD-88, Page 257

Corrosive Chemical Pumps

Buna N hard rubber body block utilized in PXHR series pumps withstands temperatures up to 225 F as well as corrosive effect of many acids, caustics and organic solvents. Design eliminates need for stuffing boxes, shaft seals, check valves or gaskets. Pump is activated by eccentric rotor and shaft assembly which rides inside molded Flex-i-liner.

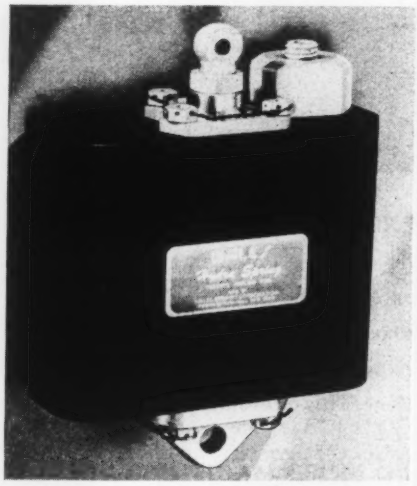
Fluid, passing on outer surface of liner and inner surface of body block, is progressively squeezed through the pump. Molded flanges on liner straddle body block and are pressed to its side by end plates sealing off fluid passage from contact with moving parts. Capacities range from ⅓ to 20 gpm with pressures from 0 to 60 psi. All units are self-priming with suction lifts up to 24 in. of mercury. Made by **Vanton Pump Corp.**, Empire State Bldg., New York 1, N. Y.



For more data circle MD-89, Page 257

Tension Spring

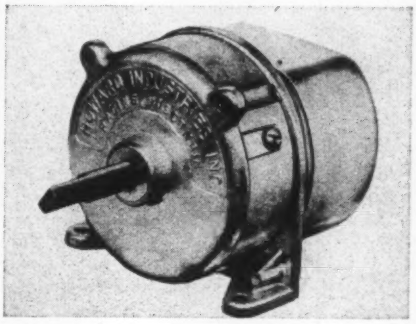
Utilizing compressibility of special fluids, the Hydra Spring pulls, rather than pushes, to increase load. It provides built-in snubbing action on the return cycle. Loads to 7000 lb and strokes to 2⅞ in. may be obtained. The units are available in any shape with fluid reservoirs placed in any location. Made by Hydra Spring Div., **Wales-Strippit Corp.**, 345 Payne Ave., North Tonawanda, N. Y.



For more data circle MD-90, Page 257

Shaded-Pole Motor

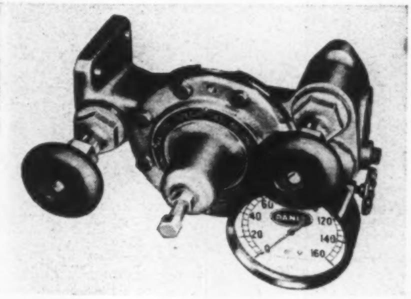
For use in vending machines and similar applications, model 3000 shaded pole motor is available in several variations with or without gear units. It is completely enclosed in an aluminum motor housing, and the gear housing, if fitted, is of two-piece design for easy access to gears. Gear ratios up to 2000 to 1 are available. The unit produces up to 120-lb-in. or without gear unit up to 1/200-hp at 3400 rpm. It can be mounted horizontally. Gears are lifetime lubricated, and motor has sleeve bearings with large oil reservoir. Made by **Howard Industries, Inc.**, 1760 State St., Racine, Wis.



For more data circle MD-91, Page 257

Air Control Manifold

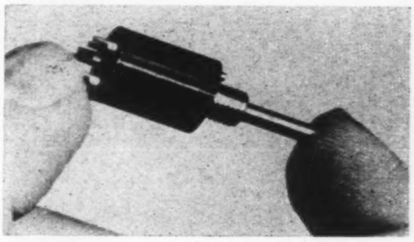
Pressure regulator, accessory valves, pressure gage and fittings normally required to control the pressure in an air line are combined in this unit. It consists of a globe shut-off valve which admits the compressed air supply, an adjustable pressure regulator, a pressure gage which is protected from line fluctuations by a needle valve, a check valve and a globe exhaust valve. Measuring 10 in. from inlet to outlet, the manifold eliminates 14 threaded joints, as well as the space and pipe fitting required to assemble this type of circuit from standard fittings. Where more than one manifold is required, special headers are used. Headers are available in two, four, six and eight-station units. Made by **Danly Machine Specialties Inc.**, 2100 South Laramie Ave., Chicago 50, Ill.



For more data circle MD-92, Page 257

Miniature Potentiometers

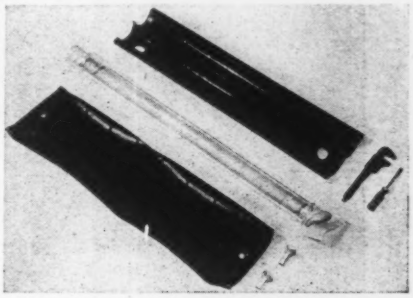
The AP-½ linear, wire-wound potentiometer is ½-in. in diameter, ⅝-in. deep, and weighs less than ½-oz. Fully sealed, it resists humidity, salt spray, shock, vibration and fungus. It operates between −55 and 85 C; at 25 C, dissipation is approximately 5 w. Soldered electrical connections, precious metal contacts to windings and slip rings, coin silver tabs to protect end turns and gold-plated forked terminals to facilitate wiring are featured. Resistances range from 10 to 10,000 ohms. Made by **Aerohm Corp.**, 282 Moody St., Waltham 54, Mass.



For more data circle MD-93, Page 257

Heat Transfer Improvers

Flexible rubber ribs vulcanized to a metal insert or flexible bag and pushed into the hollow part of a machine or strapped to the outside of a tank or pipe improve heat transfer by channeling the heat transfer medium at high velocity. Pressing against the wall to be heated or cooled, the ribs seal off the channels to direct flow of water. Water flows spirally or in other patterns, and the ribs can be built on irregular or flat surfaces. Uniform surface temperatures can be obtained through adjustment of the pitch of the rubber spirals.

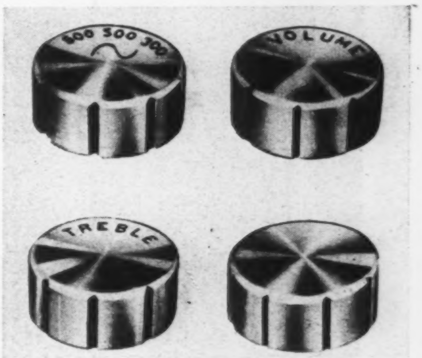


Jacket assembly, illustrated, consists of a flexible ribbed jacket and a metal cover and is available for pipe of all sizes. The jackets do not require welding, but can be installed with a wrench. Made by **F. R. Gross Co.**, 592 Crestview Ave., Akron 20, O.

For more data circle MD-94, Page 257

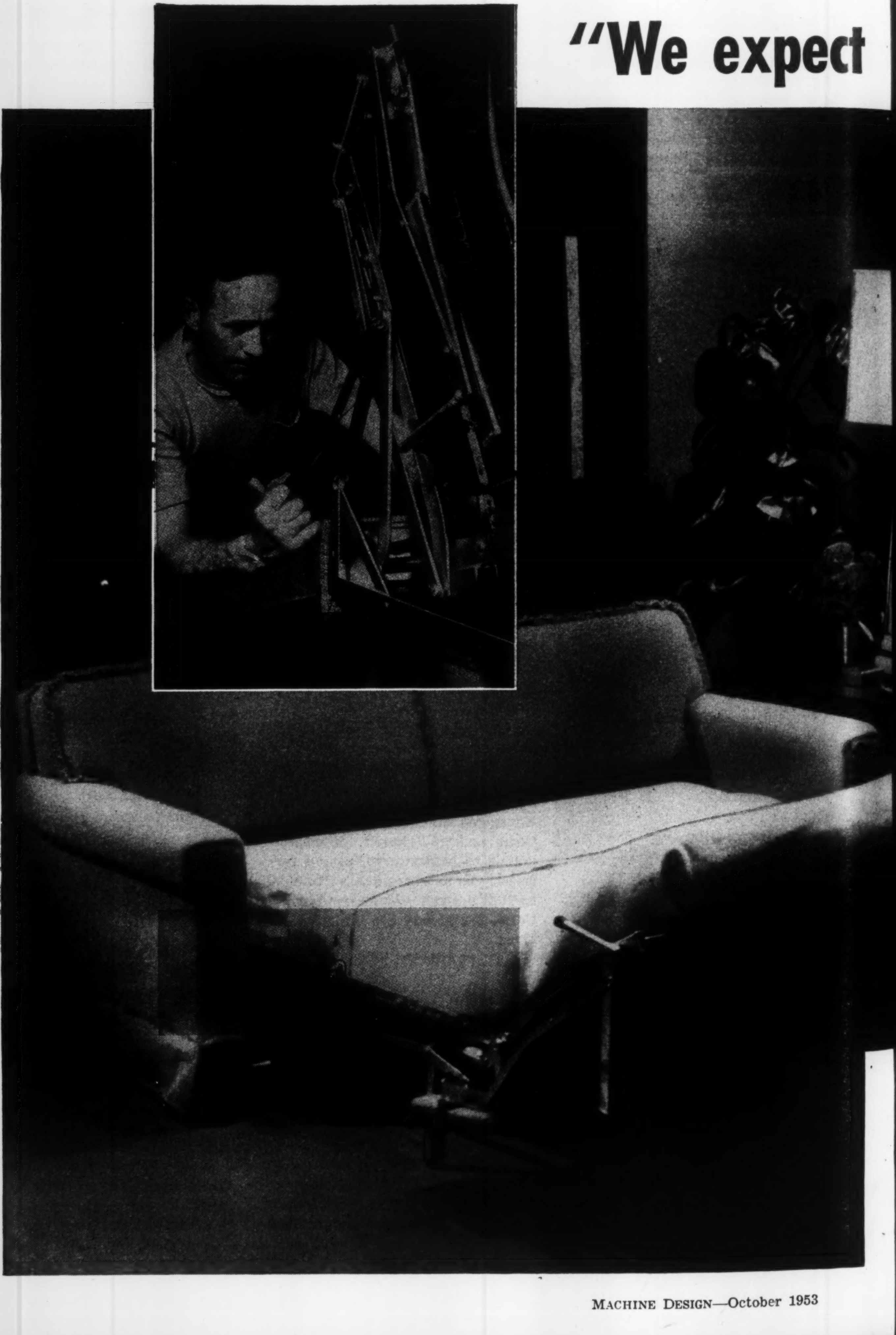
Dural Knobs

Accurately machined from dural, line of hand-machined solid knobs for electronic and industrial equipment can be engraved with any inscription with any recessed color combination. Faces of knobs have a circular satin machine finish, and the sides are fluted. Screw type mounting is provided for round or flat standard ¼-in. shafts, and knobs have back re-



(Continued on Page 276)

"We expect



20 years of service or *more* from these American Quality Springs"

...*says* SIMMONS' COMPANY

World's largest producer of sleeping equipment

EVERY housewife in America knows that the name *Simmons* is an ironclad guarantee of quality when it appears on a mattress or sofa.

If you visited any of the 7 Simmons factories, you'd know why. Simmons has built an unparalleled reputation by *insisting* on fine workmanship and highest quality component parts.

Look at the famous Hide-A-Bed shown here. You don't have to yank and pull to open it into a comfortable bed. It glides open easily on 6 counter-balance American Quality Springs. Each of these 9-inch springs must withstand a stretch to 15 inches. In a 20-year period, these 6 helical springs are stretched to the limit 14,600 times.

We produce these springs for Simmons using a high-grade oil-tempered wire. As a result, the finished springs meet very close load tolerances, and they are consistently straight.

If you need a typewriter spring, an automobile axle spring, or a spring to support a giant locomotive, American Steel & Wire will help you design it. Then we'll produce it—any size, any grade of steel, any shape, any finish. You'll get all this at a price you never thought possible.

Just call your nearest American Steel & Wire district office.

AMERICAN STEEL & WIRE DIVISION, UNITED STATES STEEL CORPORATION, GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA., SOUTHERN DISTRIBUTORS • UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS

U·S·S American Quality Springs

UNITED STATES STEEL

(*Continued from Page* 273)

cesses to clear bushing nuts and similar panel fittings. Diameters of 1, 1¼, 1½, 2 and 2½ in. are available. Made by **Pacific Transducer Corp.,** 11921 West Pico Blvd., Los Angeles 64, Calif.

For more data circle MD-95, Page 257

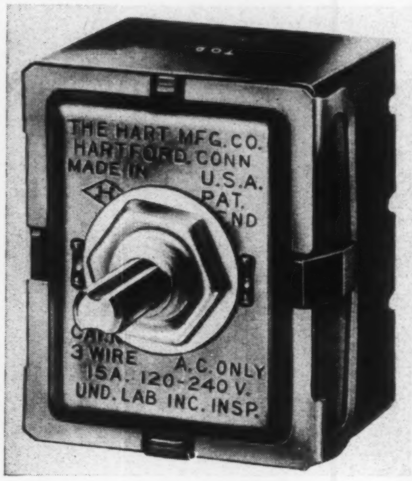
Flow Reducing Valves

Series of small flow bronze or steel reducing valves is offered for steam, air, gas or liquid service. The valves handle inlet pressures to 1000 psi and reduced pressures from 2 to 400 psi. Four sizes from 3/32 to 5/16-in. are made by **Leslie Co.,** 78 Delafield Ave., Lyndhurst, N. J.

For more data circle MD-96, Page 257

Motor Reversing Switch

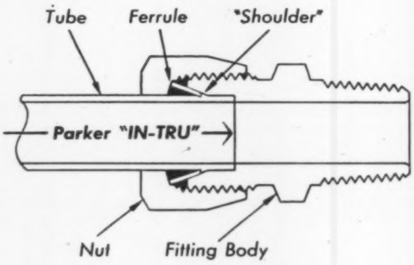
Instant, positive hook-up without binding screws or extra clips is provided by Auto-lock connections in this Diamond H model motor reversing switch. Stripped end of solid or stranded standard wire is simply pushed into the connection. Depressing small lever gives instant release. This two-pole switch is rated 1 hp at 120 v and 2 hp at 240 v ac and is designed for appliances, air conditioners, workshop power tools and similar applications involving a single-phase motor whose direction must be reversed. It measures 1 21/32 x 1 27/32 x 1 7/32 in. and is available with or without housing and with lever, pointer dial or other type handles. Made by **Hart Mfg. Co.,** 110 Bartholomew Ave., Hartford, Conn.



For more data circle MD-97, Page 257

Tube Fittings

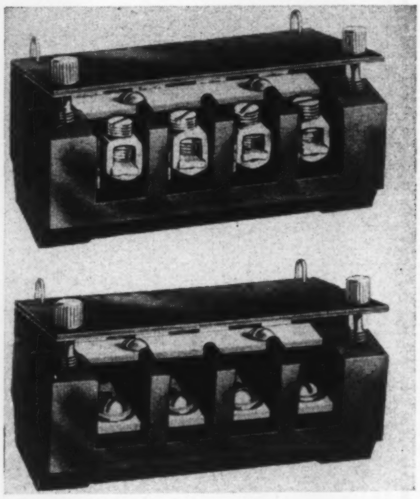
Specially suited for use in instrumentation, In-Tru tube fittings give a leakproof joint with standard wrenching assembly techniques. The resultant joints can readily be broken down for inspection or for remake. The line includes most standard connector, union and junction styles. In operation, the tube is seated and the draw nut tightened. Then, ferrule wedges into the outer surface of the tube to form a shoulder. The complete process takes a matter of seconds. Couplings are available in brass for copper tube, and in aluminum alloy for aluminum tube. Various sizes accommodate tube OD's from ¼ through 1 in. Made by **Parker Appliance Co.,** 17325 Euclid Ave., Cleveland 12, O.



For more data circle MD-98, Page 257

Terminal Blocks

Nonseparable hinged covers protect control and circuit wiring. Accessibility of connections is not affected by covers. Furnished with either screw or solderless contacts in 4, 6, 8 or 12-circuit sizes with either plain or numbered marking strips, the blocks are rated at 750 v, 35 amp for the screw type and 750 v, 50 amp for the solderless type. Made by **Buchanan Electrical Products Corp.,** 225 Highway 29, Hillside, N. Y.



For more data circle MD-99, Page 257

Wire Connector

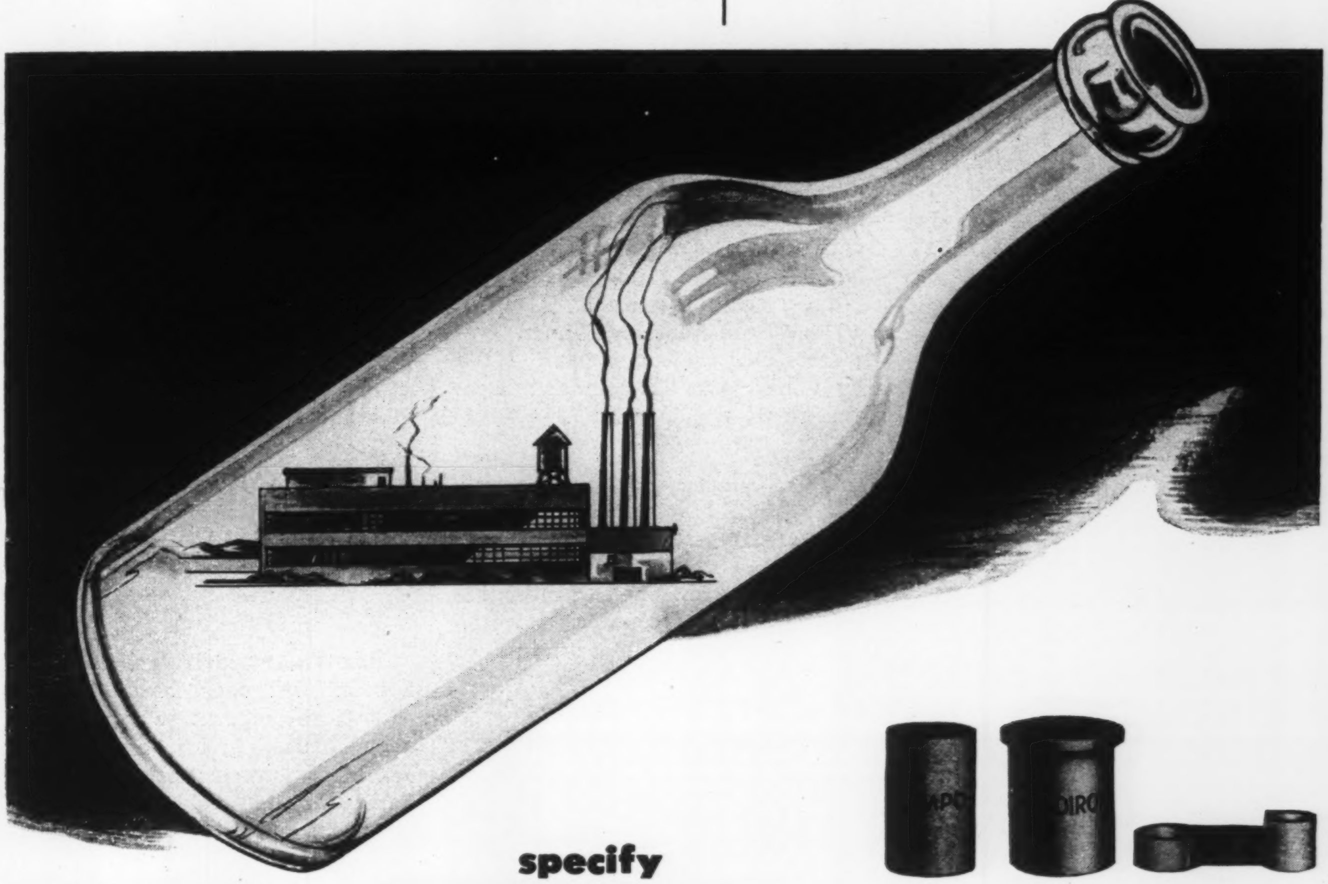
Hi-Volt porcelain connector is screw-on type for fixture wiring up to 1000 v and 600 v in other applications. Molded-in, tapered porcelain threads provide good holding power. As the connector is screwed on, it automatically twists the wires together and presses in threads which are progressively crossed as the wires are drawn further into the porcelain

Bottlenecks on the production line . . .

because machining operations slow down output?

That's **your** problem as well as the shop's!

Sure, **you** can't speed up machining, but you **can . . .**



specify

"COMPO"® and "POWDIRON"® bearings and parts

(porous bronze) (sintered iron)

that cut down the need for machining operations.

When these **bearings** are pressed into the housing, the I.D. is right without any reaming! And **parts** are die-formed to final dimensions.

The Production Department can speed up assembly—and speed up other operations, too, by using machines and operators where they're really needed.

Sales will like customers' reactions to these bearings and parts that last for years without attention.

And if you please Production and Sales, you'll probably please **Management** too!

Want to know how these oil-retaining bearings and parts—products of Bound Brook powder metallurgy—cut product costs, stand up in service? You'll find the facts you want for yourself and your management in our folder of bulletins—just write for your copy.

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BOUND BROOK
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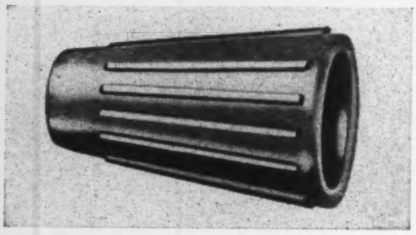
MANUFACTURERS OF BEARINGS AND PARTS • ESTABLISHED 1883

body. The connector is made of semivitreous porcelain which has a water absorption rate of 0.275 per cent. Fixture wiring to 1000 v includes two or three No. 18, two No. 16, and one No. 18 with No. 16 wires. The connector can also be used as fixture splicing type up to 300 v. Made by **Holub Industries Inc.,** 413 DeKalb Ave., Sycamore, Ill.



For more data circle MD-100, Page 257

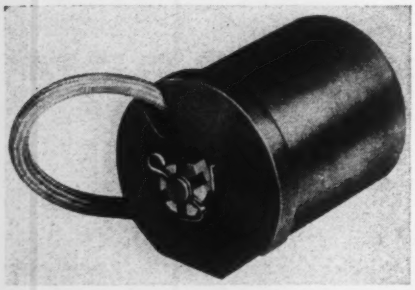
Dry Film Lubricant

An easily identifiable green lubricant can be applied by spraying, dipping or brushing. It locks to the part, diffuses into preparatory surface coatings, and creates a lap-in action. The material has excellent oil retention properties, is unaffected by solvents and is also abrasion resistant. Developed by **Everlube Co.,** 4435 B San Fernando Rd., Glendale, Calif.

For more data circle MD-101, Page 257

Solenoid

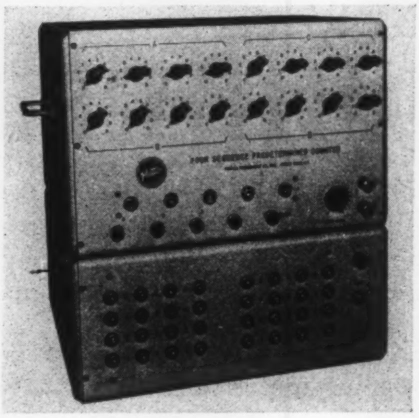
Designed to specifications for jet aircraft fuel control systems, this linear proportional solenoid is now available for other commercial and military uses. In aircraft application, it operates in direct linear proportion to the amplified energy produced by a thermocouple but is applicable to other systems requiring the proportional transfer of electrical energy to linear mechanical movement. Coil resistance is 2900 ohms, ±5 per cent. With compression load on plunger of 75 grams, plunger travel with 0 to 10 ma current is 0.0015-in. minimum; with 10 to 30 ma current, travel is 0.012-in. ±0.001-in. Linearity of plunger travel is within ±1 ma in 10 to 30 ma range. Maximum hysteresis is equivalent to 2 ma. Made by **Connecticut Telephone & Electric Corp.,** Meriden, Conn.



For more data circle MD-102, Page 257

Predetermined Counter

Available for one or more sequences, this counter governs machinery operation in terms of lineal measurement, shaft revolutions, quantity, volume or weight at speeds as high as 60,000 per minute. Offering precise control, the counter is not affected by speed changes, shutdowns, etc. Made by **Potter Instrument Co. Inc.,** 115 Cutter Mill Rd., Great Neck, N. Y.



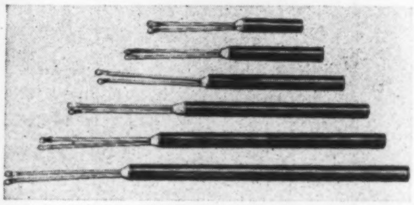
For more data circle MD-103, Page 257

Plastic Tubing

Adaptable for use on equipment operating at extremely low temperatures, Airflex No. 6904 clear plastic tubing is approved under Air Force specification MIL-I-7444A. It has high flexibility at low temperatures and is fungus resistant. Application can be as primary and secondary insulation, wire harness sheathing, wiring conduit where abrasion resistance is needed and as a fluid drain or transfer medium. Made by **Irvington Varnish and Insulator Co.,** Fibron Division, Irvington 11, N. J.

For more data circle MD-104, Page 257

Heating Element



The Thermacartridge, developed for high watt densities and long life in critical temperature applications, may be used in injection molding machines, preplasticizers, heating forms for shell molding, etc. Close tolerance on the outside diameter facilitates installation in a reamed hole. Available in lengths from 1 in. to 12 ft and in diameters from ⅜ through ¾-in. from **Thermel Inc.,** 3440 West Lake St., Chicago 24, Ill.

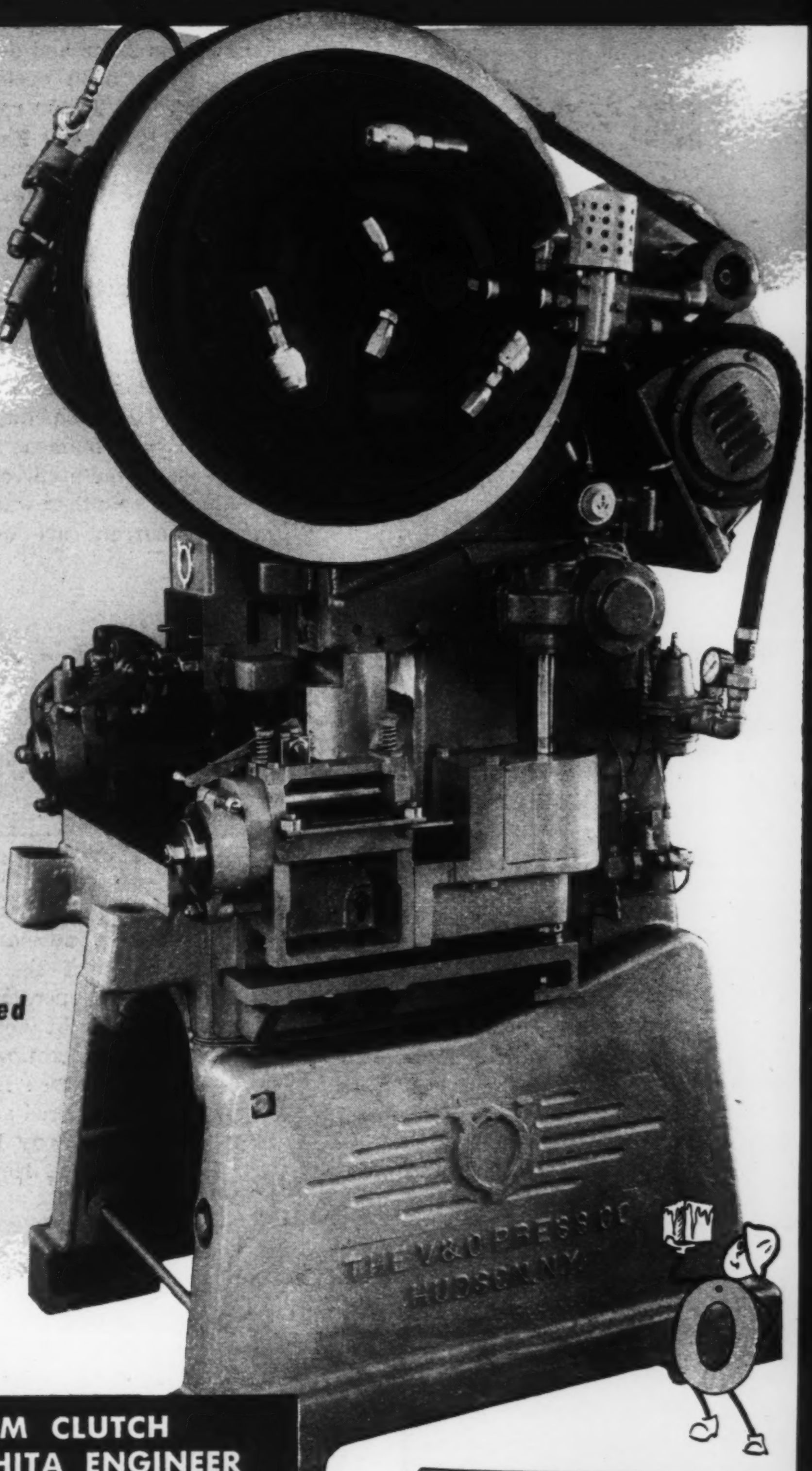
For more data circle MD-105, Page 257

Electronic Timer

Providing timed delay periods, intervals or other programming between 1/10 and 60 seconds, type 60MC electronic timer can be operated from momentary or sustained contact such as foot switch, push-button or pressure switch. Intervals are unaffected by variation in line voltage or frequency. Unit is enclosed in a gray wrinkle finish steel box, measuring 9 x 7 x 4½ in., with hinged cover and knockouts. Applications include incorporation for control in bag and bottle filling, ceramic and injection molding, hydraulic presses, rubber curing and spot welding. Operating on 105-125 v, 50 or 60-cycle current, the

Wichita . . . the Answer to

CLUTCH PROBLEMS for HIGH SPEED OPERATIONS!



To have perfect control on high speed presses operating at 450 Strokes Per Minute, clutches must disengage very quickly, because the elapsed time is extremely short between the ram at the bottom and at the top center. This is a major requirement on 45 ton V & O High Speed Presses. Because Wichita 18" Low Inertia Clutches are the answer to this and many other press clutch problems . . . WICHITA CLUTCHES WERE SELECTED.

In addition, the extremely fast action, of Wichita Clutches and Brakes, is ideal for inching (or jogging) and single stroke operation.

The Wichita Clutch on the press pictured here has been operated in excess of 100 engagements per minute WITHOUT DEVELOPING ANY TROUBLE . . . HEAT INCLUDED!

WICHITA Low Inertia, Positively Ventilated CLUTCHES Will Eliminate:

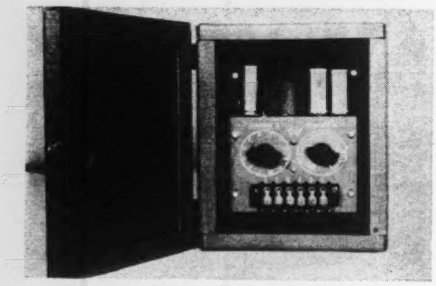
- **Heat Problems**
- **Adjustment Problems**
- **Lubrication Problems**
- **Centrifugal Force Problems**
- **Self Energization Problems**

TO GAIN MAXIMUM EFFICIENCY FROM CLUTCH OPERATION SEE YOUR NEAREST WICHITA ENGINEER

WICHITA DISTRIBUTORS

Brehm-Lahner, Inc., Detroit, Michigan
L. H. Fremont, Cincinnati, Ohio
W. G. Kerr Company, Pittsburgh, Pa.
Smith-Keser & Co., (Main Office) West Hartford, Conn.
Smith-Keser & Co., Philadelphia 44, Pa.
Smith-Keser & Co., New York, N. Y.
Frank W. Yarline Co., Chicago, Ill.
Power Rig & Equipment Co., Inc., Long Beach, Calif.
Robert R. King Co., Cleveland, Ohio

WICHITA Falls
WICHITA FALLS, TEXAS U.S.A.



timer has normally open, single-pole, double-throw 10-amp contacts. Made by **G. C. Wilson & Co.,** 2 North Passaic Ave., Chatham, N. J.

For more data circle MD-106, Page 257

Molding Compound

Durez 16221 Natural is supplied in a dry form consisting of rovings of Fiberglas impregnated with a phenolic resin. It provides a maximum impact strength of 26 ft-lb per inch, a tensile strength of 24,000 psi, and flexural strength of 65,000 psi. Parts made of the material provide long, hard wear, heat resistance, and good insulation. Applications include heavy-duty insulators, brackets, and spring cups. Made by **Durez Plastics and Chemicals Inc.,** North Tonawanda, N. Y.

For more data circle MD-107, Page 257

Alternators

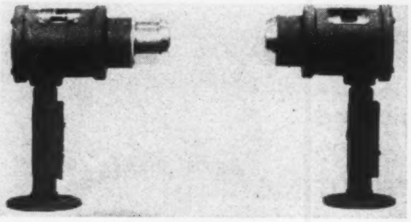
With power output ratings from 125 to 4000 w at 5000 cycles per second, these miniature high-frequency alternators have extremely high power outputs for their size and weight. Operating shaft speeds range from 10,000 to 50,000 rpm. Illustrated is Model A-17, which measures 2½ in. in diameter, weighs 22 oz and delivers 350 w output at 5000 cycles with a shaft speed of 25,000 rpm. Made by **D & R Ltd.,** 402 East Gutierrez St., Santa Barbara, Calif.

d&r LTD.
SANTA BARBARA, CALIFORNIA
ALTERNATOR
5000~ 350W
25,000RPM
MOD. No. A-17
SER. No. 329-1

For more data circle MD-108, Page 257

Photoelectric Controls

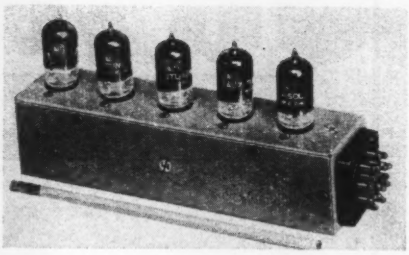
Unaffected by stray ambient light, these controls utilize cold cathode tubes, which eliminate complex circuitry, filament and plate transformers and high-voltage power supplies. Neither warm up nor stand-by current are needed. A precision lens system, as well as a vernier focusing adjustment, permits utilization of the apparatus for either distant operation employing a parallel light beam or for short pin-point operations employing a sharply focused light beam. The lens can be locked at any position. Made by **Haledy Electronics Co.,** 57 William St., New York 5, N. Y.



For more data circle MD-109, Page 257

Binary Counter

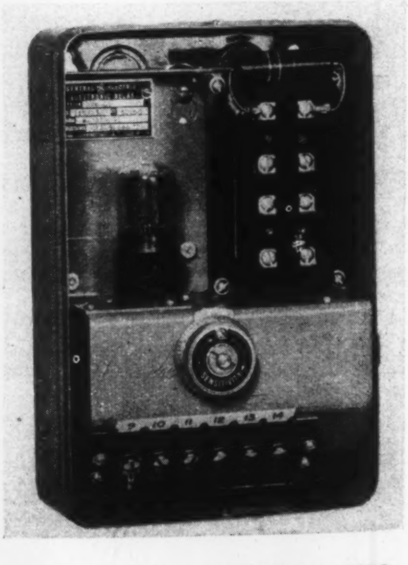
Model 1001, a magnetic nine-stage binary counter plug-in package counts at rates up to 50 kc. It can be applied to perform such functions as integration, addition, multiplication and division when used in conjunction with other plug-in packages. The unit has low power requirements, wide tolerance on power supply variations and minimum number of tubes. It is 2 by 2 by 8 in. long. Made by **Laboratory for Electronics Inc.,** 75-4 Pitts St., Boston 14, Mass.



For more data circle MD-110, Page 257

Electronic Relay

Suitable for indoor or outdoor installation, this relay is highly sensitive to resistance changes, and sensitivity can be varied by a stepless dial. It starts or stops a fractional-horsepower motor directly when a contact making ammeter, voltmeter or wattmeter reaches a required meter reading. Other uses include liquid-level control, sorting of small parts and operation of lights, solenoids and contactors wherever sufficient change takes place in the resistance of a circuit. Two single-pole double-throw contacts permit control of independent systems, and a simple jumper change sets the relay for normal or reversed operation. A sensitivity dial located on the front of the unit may be remotely con-



When Nobody Knows the Answer

One of these days you may come face-to-face with a metal problem that does not seem to have an answer.

That is the time to think of these International Nickel Company metallurgists. They are constantly improving and modifying nickel alloys to meet new conditions. They are always ready to help you with specific problems involving metals for destructive service conditions.

Over the past 50 years, Inco has developed a family of metals for hundreds of different applications. In one branch of the family, for example, is a group of heat-resisting alloys—Inconel®, Inconel "X"®, the Nimonic® Alloys and Incoloy®—all now important in high temperature work.

Elsewhere on the family tree, you will find other alloys — each with certain special characteristics. Often, there is a better-than-even chance that one of Inco's alloys offers exactly the properties you are looking for.

Of course, this does not mean that somebody at Inco can dip into the files and come up with a pat answer to every new problem. All the answers have not been found yet. But a tremendous amount of research has been done, and you can probably benefit in one way or another from it.

When nobody knows the answer, Inco's metallurgists keep going until they have investigated all possible metals and alloys that might do the job. In fact, the men in Inco's Technical Service (and in their Corrosion Engineering and High Temperature Engineering Services, as well) have one primary goal: to help you determine whether an Inco Nickel Alloy or some *other* metal will serve your purpose best.

No matter what your metal-selection problem may be, all the technical facilities of Inco are available to help you solve it. There is no charge, no obligation of any kind. For prompt technical help whenever you need information about metals, all you have to do is get in touch with: "Technical Service,"

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"S"® MONEL • INCONEL® • INCONEL "X"® • INCONEL "W"® • INCOLOY®
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Ground to be round . . . round all over . . . within ten-millionths of an inch. Universal Precisioneered Balls are as accurate as the fixed stars! Mirror-smooth with minimal torsional resistance for oscillating conditions. Silent in operation at high speeds.

Quality-controlled Universal Precisioneered Balls of chrome and stainless steel are universal favorites. We also produce balls from bronze, aluminum, and other materials . . . all 100% inspected, all individually gauged.

For special instrument applications, we produce balls guaranteed accurate within .000005″.

Universal Ball co.

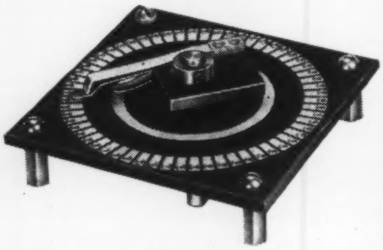
WILLOW GROVE
MONTGOMERY CO., PA.

trolled from 500 ft away and may be locked when set. Power requirements are 115/230 v ac, 50 or 60 cycles, and should not exceed 10 va. Contact rating is: inrush, 30 amp; carry, 10 amp; break, 10 amp on normally closed contacts and 5 amp on normally open contacts. Break inductive load for 125 v dc is 0.2-amp normally open and 0.1-amp normally closed; for 250 v dc, it is 0.1 normally open and 0.05 normally closed. Time delay is rated at 5 milliseconds minimum. The enclosure measures approximately 10 by 6¼ by 4⅞ in. Made by **General Electric Co.,** Schenectady 5, N. Y.

For more data circle MD-111, Page 257

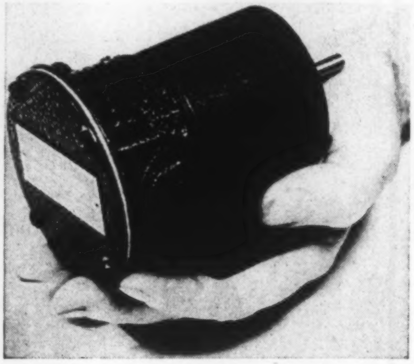
Rotary Switch

Stator contacts of the 60-position switch are silver and rhodium-plated copper printed on a 3-in. square paper-base phenolic deck. Connections are made to stator contacts through eyelet terminals. Featuring an isolated shaft, the switch is designed for four-point spacer mounting so that a number of units may be ganged. Contacts make before break. Made by **Shallcross Mfg. Co.,** Collingdale, Pa.



For more data circle MD-112, Page 257

Contactors

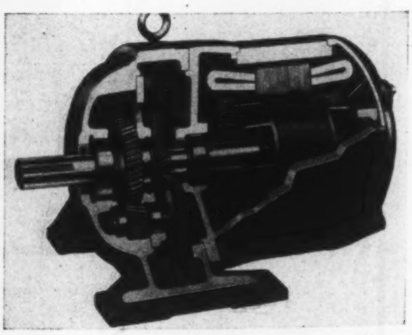


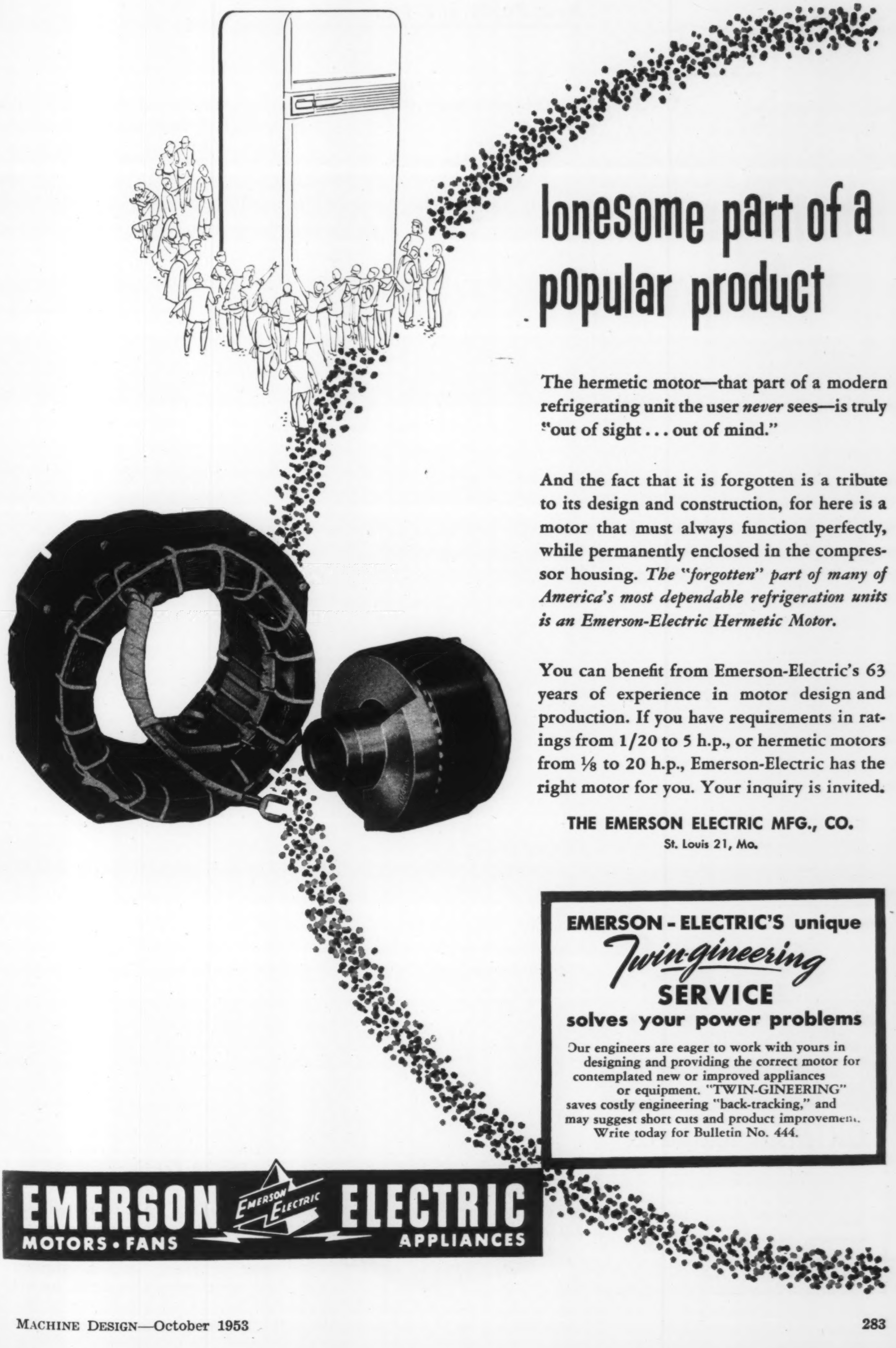
A series of Dazic all metal zero speed switches are equipped with single-pole, snap-action contacts rated at 10 amp at 110 v ac. The units are self-lubricating and have hydraulically driven mechanism and magnetically coupled electrical contacts. They can be wired to open or close signal circuits on shaft rotation of 15 rpm on acceleration and 8 rpm on decreasing shaft speed. Direction of rotation is indicated, as well as idling when shaft is stationary. The switches operate at speeds to 5000 rpm and at temperatures from −20 to 250 F. Required driving torque is 3 in.-oz. The units can be mounted in any position. Made by **Winterburn Mfg. Co.,** Whitmore St., Putnam, Conn.

For more data circle MD-113, Page 257

Gearmotors

Featuring a wide selection of power units with single, double, or triple speed reduction, gearmotors are available in a range from 1 to 150 hp. Units employ any Crocker-Wheeler motor including squirrel-cage, wound rotor, or multi-speed in open-protected, splashproof, totally-enclosed nonventilated, totally-enclosed fan-cooled and explosionproof enclosures. Mounting can be horizontal, ceiling, sidewall or inclined. Features include positive oil seal between gears and highspeed bearings, large oil reservoir and locked motor shaft





lonesome part of a popular product

The hermetic motor—that part of a modern refrigerating unit the user *never* sees—is truly "out of sight . . . out of mind."

And the fact that it is forgotten is a tribute to its design and construction, for here is a motor that must always function perfectly, while permanently enclosed in the compressor housing. *The "forgotten" part of many of America's most dependable refrigeration units is an Emerson-Electric Hermetic Motor.*

You can benefit from Emerson-Electric's 63 years of experience in motor design and production. If you have requirements in ratings from 1/20 to 5 h.p., or hermetic motors from ⅛ to 20 h.p., Emerson-Electric has the right motor for you. Your inquiry is invited.

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solves your power problems

Our engineers are eager to work with yours in designing and providing the correct motor for contemplated new or improved appliances or equipment. "TWIN-GINEERING" saves costly engineering "back-tracking," and may suggest short cuts and product improvements. Write today for Bulletin No. 444.

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Available in a full range of sizes (1½" to 8" bores) with standard, 2 to 1 or oversize rods. All machined steel with bearing bronze, no castings. Completely interchangeable parts.

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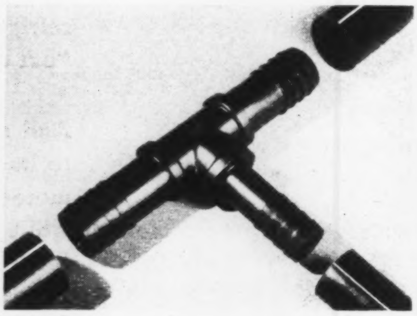
City................**Zone**...**State**....

pinion to minimize vibration on reversing service. Made by **Elliott Co.**, Crocker-Wheeler Div., Ampere, N. J.

For more data circle MD-114, Page 257

Plastic Reducer Fitting

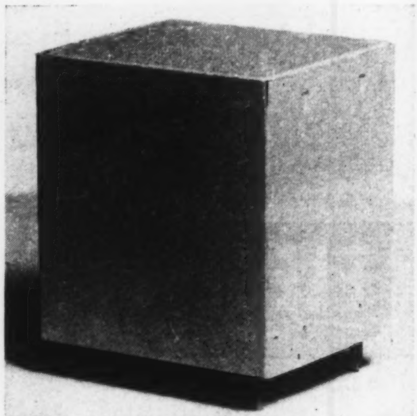
The side outlet is one standard pipe size smaller than the run; the fitting is available in run sizes up to 2 in. Molded from one piece of thermoplastic material and resistant to rot, rust and electrolytic corrosion, the T-fitting is joined to plastic pipe by the same method used for standard insert couplings. Made by **Carlon Products Corp.**, 10225 Meech Ave., Cleveland 5, O.



For more data circle MD-115, Page 257

Magnetic Amplifier

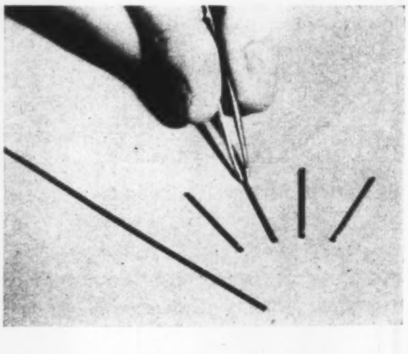
Model M-21 miniature high-gain magnetic amplifier produces a usable dc output from a 1/5-microampere input signal. Featuring a linear current gain of 200 up to 30 microampere input, it delivers 1 milliampere with an input of 5 microamperes into a load of 100 ohm. Stability is maintained with a zero drift less than 10^{-15} w. Small size —2¼ by 2¼ by 3 in.—is possible because of a push-pull circuit which has two cores in place of the usual four. Intended for low-level applications, the unit can be used as the main amplifier or preamplifier in controls using thermocouples, barrier type photocells, thermistors and other low-level sending devices. Made by **Rubissow Electron Research Laboratories,** 119 West 63rd St., New York 23, N. Y.



For more data circle MD-116, Page 257

Small Size Tubing

Commercially pure titanium tubing in sizes from ⅛ to 1½ in. OD, with wall thickness from 0.004 to 0.187-in. in both seamless and Weldrawn grades can now be obtained for use in the chemical processing, pharmaceutical and aircraft industries. Outside diameters as small as 0.0455-in. with wall thickness of 0.00225-in. have been drawn. To avoid embrittlement, all thin-wall titanium tubing is annealed. Made by **Superior Tube Co.,** Germantown Pike, Norristown, Pa.



For more data circle MD-117, Page 257

Protective Coatings

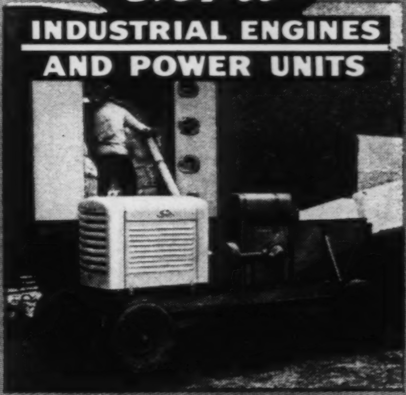
Nerva-Kote TAE room temperature cured coatings protect metallic and nonmetallic surfaces. They show excellent impact, abrasion and weathering properties, as well

A "MOVING" STORY IN PICTURES Starring Ford

INDUSTRIAL ENGINES AND POWER UNITS

Knickerbocker "truck-man"

Wayne Motor Pick-Up Sweeper

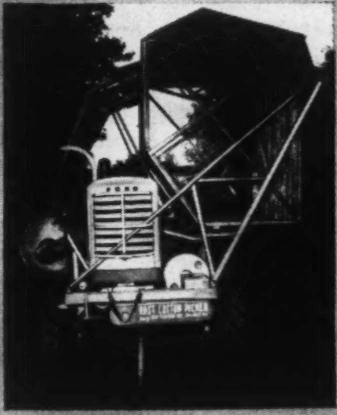

Tri-Pak Ice Crusher

Gerlinger Carrier

Lessman Power Shovel

Athey Force-Feed Loader

Coles Crane


RUST Cotton Picker

Standard Steel Bituminous Spreader

The pictures above only partially indicate the wide variety of mobile machinery in which Ford Heavy Duty Industrial Engines and Power Units are standard equipment. Designers and engineers are invited to write for descriptive literature on Ford's 6 Great Engine Series . . . ranging from 134 cu. in. to 317 cu. in. displacement. It will pay you to know about the Right Features, the Right Power, the Right Service always available when you *specify* FORD! Write or wire us for detailed information—today!

INDUSTRIAL ENGINE DEPARTMENT
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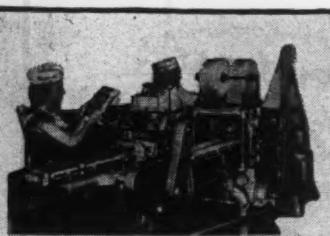
Your Job is WELL-Powered When it's FORD-Powered!



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Toledo, Ohio

"LUBRIPLATE greatly reduces unnecessary wear and prolongs the life of machines. It has reduced customer calls for service to a minimum. Our Service Engineers can readily spot machines that have had other than LUBRIPLATE Lubrication, as these machines do not give the service they should."

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REGARDLESS OF THE SIZE AND TYPE OF YOUR MACHINERY, LUBRIPLATE LUBRICANTS WILL IMPROVE ITS OPERATION AND REDUCE MAINTENANCE COSTS.

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THE MODERN LUBRICANT
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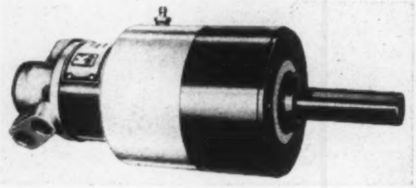
PREVENTS WEAR AND CORROSION
LUBRIPLATE
SUPER-LUBRICATION
MANUFACTURED IN U. S. A. BY
FISKE BROTHERS REFINING CO.
NEWARK, N. J. — TOLEDO, OHIO

as good cold check qualities. They resist alcohols, water and hydrocarbon solvents; alkalies at most concentrations up to 190 F; ketones and esters and show good resistance to low concentrations of acids. They are also resistant to salt spray. An application of the material dries in 6 to 8 hours. Nerva-Kote Div., **Rubber & Plastics Compound Co. Inc.,** 30 Rockefeller Plaza, New York 20, N. Y.

For more data circle MD-118, Page 257

Air Motors

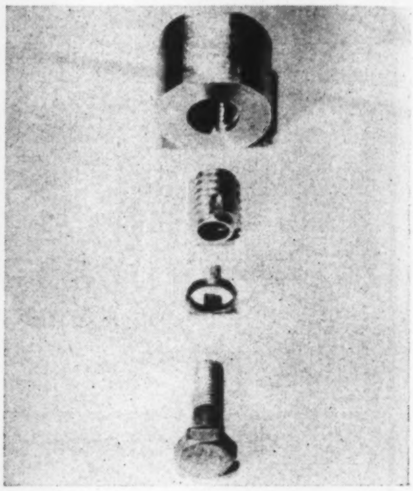
Compact and instantly reversible, series 70A air motors are available in ratings from 1/2 to 2 3/4 hp in 12 speed and torque combinations. They feature an axial piston design, which results in air consumption figures ranging between 21 and 83 cfm, dependent upon horsepower. Speeds are infinitely variable from zero to full rpm, and consistent torque output is achieved on low as well as high air pressure. Made by **Keller Tool Co.,** Grand Haven, Mich.



For more data circle MD-119, Page 257

Inserts and Studs

Kelox method of fastening provides positive locking against rotative action by means of a ring key. Installation or removal of either insert or stud is accomplished without special tools. A smooth ring has two keys which fit into a keyway in the insert or stud. When pressed into position the keys cut through sufficient threads of the parent body tapped hole to provide a positive key-to-keyway lock. This method can be used on thin plates as well as heavier structural sections, and the fastener can be applied close to edges, since it creates no lateral stresses that would normally cause splitting or other damage. Developed by **Fasteners Inc.,** 1 West 47th St., New York 36, N. Y.



For more data circle MD-120, Page 257

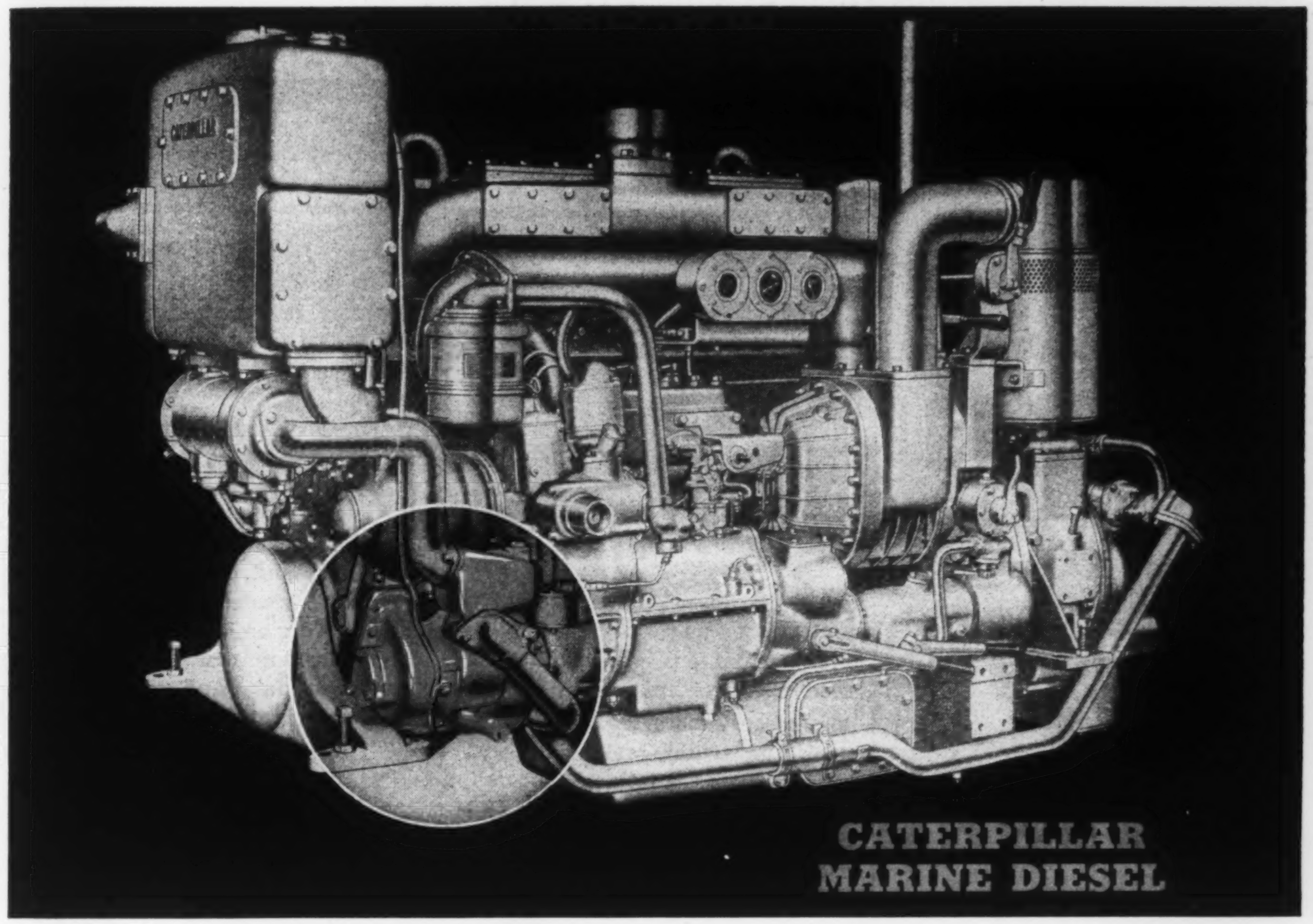
Silver Alloy

With good flow characteristics on tungsten carbide, difficult to braze alloys and steels, EutecRod 1602 is a silver brazing type alloy. It flows well even at elevated temperatures, and will produce brazed joints on alloys which have refractory oxides of chromium, nickel, vanadium, etc. It requires but low heat input for T and butt joints where a "white" solder-type alloy is desired on stainless steel. It is available in rod diameters of 3/64, 1/16, 3/32 and 1/8-in. Made by **Eutectic Welding Alloys Corp.,** Dept. P, 172nd St. & Northern Blvd., Flushing, N. Y.

For more data circle MD-121, Page 257

Thermostat

For extremely high temperature applications in jet engines, gas turbines, after burner controls or whenever temperature warning is required to 2000 F, type ASA-21-2 is a nongrounded switch and has maintained set calibration for 100 hours at 1500 F with a variation



CATERPILLAR
MARINE DIESEL

National Bearing Castings Help Cool "Cat" Engines

National Bearing Division's foundry skill permitted a new design in pump efficiency and compactness.

This extremely compact 170 horsepower Marine Diesel Engine, with special coolant pump, is a new design in efficiency by Caterpillar Tractor Co., Peoria, Illinois, makers of famous "Caterpillar" Diesel Engines, Tractors, Motor Graders, and Earthmoving Equipment.

Unusual size restrictions were specified in the coolant pump housing. It had to be of tough, durable bronze, highly resistant to corrosion by raw sea water, and painstakingly cast as the housing component for a very compact coolant pump, capable of delivering 100 gallons per minute. The housing casting design was unusually intricate, with wall thicknesses exactly $\frac{1}{4}''$ in some areas, $\frac{7}{32}''$ in others. The mold for each casting required *14 cores*—all perfectly positioned, as the slightest misalignment would be ruinous. And, housings had to be cast to minimize machining.

"Caterpillar" selected National Bearing Division to provide these special bronze pump housings. We were chosen for proven ability to produce top quality castings, our unique core facilities, and our experience in applying over 50 years of specialization to customers' problems.

Our bronze pump housing castings met—and continue to meet — "Caterpillar's" specifications for quality, tolerance, and minimum machining in every respect.

If your product includes copper, bronze, or other copper-base castings, it will be worth your while to investigate National Bearing Division. We produce copper-base castings, large or small, with any degree of finish, to precision specifications. And, because we are set up for production runs, we can probably save you dollars.

Write to National Bearing Division for complete information and your copy of our catalog.

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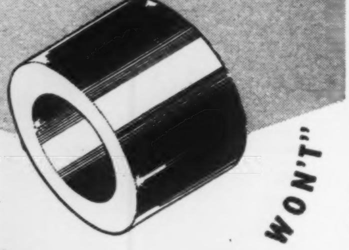
OIL-FREE
SELF-LUBRICATING
BUSHINGS



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Widely Used Where Ordinary Oil Lubrication Is Impractical or Impossible.

EXCELLENT DURABILITY • CONSTANT CO-EFFICIENT OF FRICTION • APPLICABLE OVER A WIDE TEMPERATURE RANGE — EVEN WHERE OIL SOLIDIFIES OR CARBONIZES • OPERATE DRY, OR AT HIGH SPEEDS SUBMERGED IN WATER, GASOLINE AND OTHER LIQUIDS • EXCELLENT FOR CURRENT-CARRYING BEARINGS

GRAPHALLOY materials are also in wide use for oil-free, self-lubricating piston rings, seal rings, thrust washers, friction discs, pump vanes etc.

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For applications requiring low electrical noise, low and constant contact drop, high current density and minimum wear. Used for SELSYNS, DYNAMOTORS, SYNCHROS, ROTATING STRAIN GAGE pick-ups and many other applications. Brush Holders and Coin Silver Slip Rings also available.

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NAME & TITLE
COMPANY
STREET
CITY ZONE STATE

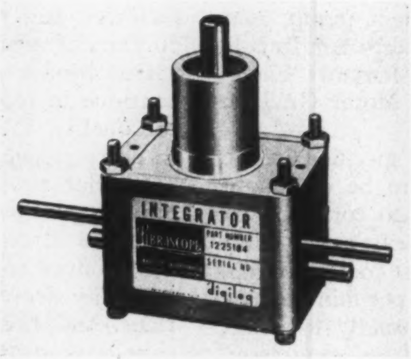
of only 10 F. It withstands any degree of overshoot or undershoot up to the ability of the metal to stand the temperature rise and also offers maximum vibration resistance. Contacts are welded on flexible arms. Constructed of stainless steel, the switch weighs approximately 6 oz. Available normally open or normally closed from **Control Products Inc.,** Sussex St., Harrison, N. J.

For more data circle MD-122, Page 257

Integrator

Ruggedly constructed, this small ball and disk integrator is a precision mechanism for totalizing, rate determination and differential analyzing. It can also be used as a closed loop servo element or an accurate variable speed drive. Precision (reproducibility) is 0.01 per cent. Force required to move the ball carriage is $2\frac{1}{2}$ oz; ball carriage shaft travel is $1\frac{1}{2}$ in. Minimum input torque required at zero load is 2 oz-in. Enclosed in an aluminum alloy case, the integrator weighs 21 oz. Made by **Librascope Inc.,** 1607 Flower St., Glendale, Calif.

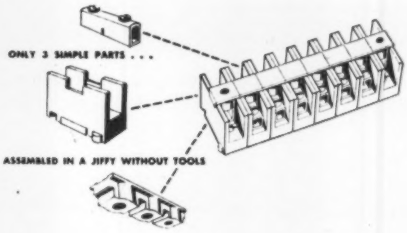
For more data circle MD-123, Page 257



Molded Terminal Blocks

Consisting of three parts which can be quickly assembled without tools, Lok-A-Blok terminal blocks can be assembled in lengths and combinations up to 25 poles without waste. Parts consist of solderless copper connectors, connector housings, and a strip tying housings and connectors together and also serving as identification marking. The top can be marked by pencil or ink, and moldings are colored bright red and yellow. On live metal parts the assemblies have a $\frac{3}{4}$-in. clearance "over surface" and a "through air" clearance of $\frac{1}{2}$-in. Made by **Ilsco Copper Tube & Products Inc.,** Mariemount Ave., Cincinnati 27, O.

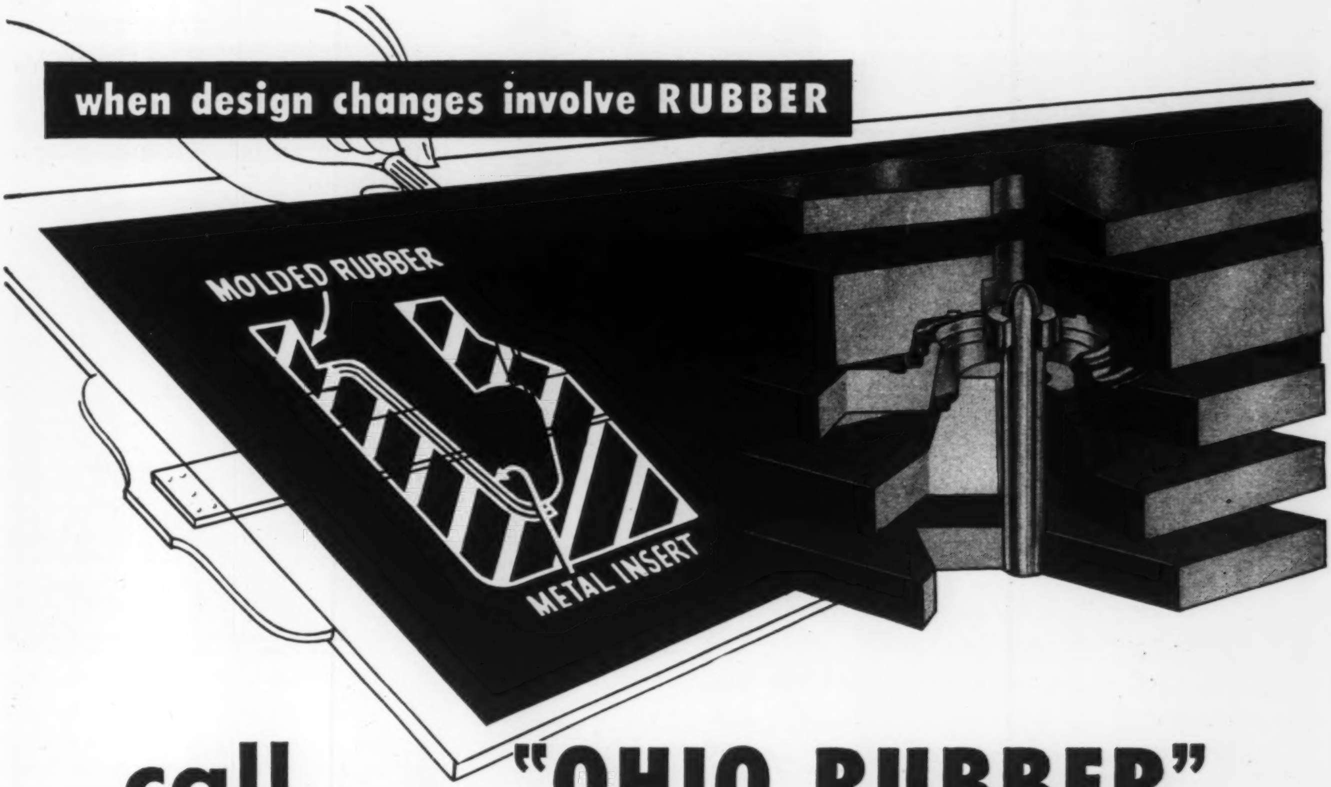
For more data circle MD-124, Page 257



Insulation

Surfaces sprayed with quick-drying Pyrolock can withstand temperatures to 5000 F. A 1/16-in. coating provides protection against flame temperatures hotter than the melting point of metals for 10 seconds. This water-base inorganic material is nontoxic, nonflammable, nonexplosive and will adhere to clean metal surfaces without preliminary sandblasting or use of surface primers. The dried layer, bonded to the metal, withstands sharp impact short of actual deformation of the base metal. It is resistant to most solvents and

when design changes involve RUBBER



call . . . . . "OHIO RUBBER"

Here's the quick story back of the above views. Shown at right is a cut-away view of a multiple-cavity mold. Shown at left is a cross-section drawing of a rubber part with molded-in metal insert. A lot of problems were involved in designing the mold to produce the part. But there were other problems too. Selecting and compounding the right rubber for the purpose. Bonding the metal insert to the rubber. Employing the most efficient production techniques to meet customer's specifications and save him money.

We cite that example as one of almost countless rubber parts we have produced for American manufacturers in our 60 years of specialization in the field of rubber. Here is a wealth of experience available to you in a single, reliable source. That's why we say *"When Design Changes Involve Rubber*—CALL OHIO RUBBER".

For quick action, 'phone us at
WILLOUGHBY (OHIO) 2-0500.
Or use the convenient form at
the right.

THE OHIO RUBBER COMPANY
A Division of The Eagle-Picher Company
129 BEN HUR AVE. • WILLOUGHBY, OHIO

We are interested in knowing more about your facilities and services in connection with our specific problems in rubber. Please have your sales engineer in our area see us as soon as possible.

MY NAME ______________________

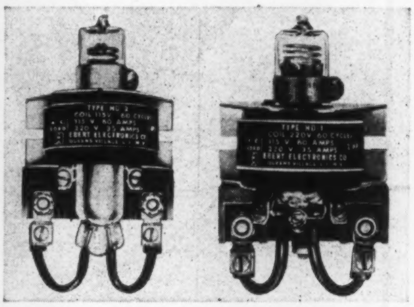
COMPANY ______________________

STREET ______________________

CITY ____________ ZONE ______ STATE ____________ chemicals and also withstands temperature cycles of −60 to 165 F. Developed by **B. F. Goodrich Co.,** Industrial Products Div., Akron, O.

For more data circle MD-125, Page 257

Mercury Contactors



Models HD-1 and HD-2 are for heavy-duty control applications. Ratings are 60 amp for 115 v ac and 35 amp for 230 v ac application; 12 amp at 120 v, 7 amp at 240 v dc. Horsepower ratings are 2 hp at 115 and 230 v ac and ½-hp at 120 or 240 v dc. Model HD-1 is normally open; model HD-2 is normally closed. Both feature mercury-to-mercury contacts and are chatterfree, hermetically sealed and explosion-proof. Overall dimensions are 4¼ by 2⅝ by 2¼ in. Made by **Ebert Electronics Co.,** 212-26 Jamaica Ave., Queens Village 28, L. I., N. Y.

For more data circle MD-126, Page 257

Plastic Molding Material

Sheets, rods, tubes and molded shapes made of Plio-Tuf offer great impact strength and toughness, as well as high heat resistance and tensile strength. The Plio-Tuf resins can be plasticized with rubber to further increase impact strength. Complex shapes are formed by ordinary plastic molding techniques. Products molded from the resins, such as automotive parts and plastic pipe, are acid, alkali and stain-resistant. Developed by **Goodyear Tire & Rubber Co.,** Akron, O.

For more data circle MD-127, Page 257

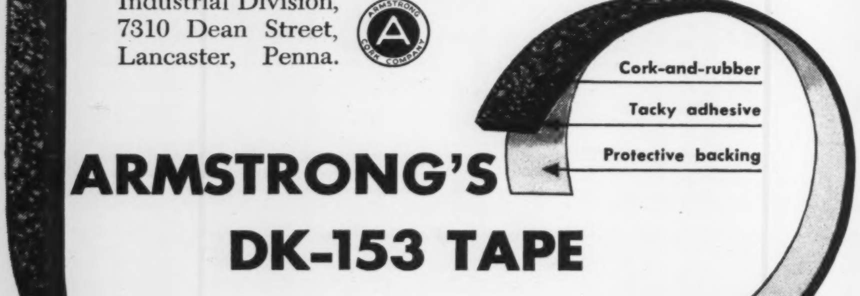
This cork-and-rubber tape sticks to its sealing job

The cover gasket of an electrical junction box must stay in place no matter how many times the box is opened. Box manufacturers find Armstrong's DK-153 Tape ideal for this unusual sealing job.

This springy cork-and-rubber tape has a pressure-sensitive adhesive backing that holds the gasket firmly in place when cover is removed. The adhesive backing speeds production, too, for to apply a gasket, you simply peel off the protective cloth and press the part into place.

DK-153's resilience makes it ideal for many other jobs besides gasketing. For example, the tape is widely used to pack delicate parts for protection from shipping damage or to provide anti-skid pads.

You can get Armstrong's DK-153 Tape in a variety of widths and thicknesses, in sheets, rolls, ribbons, and die-cut shapes. For samples, write on your letterhead to Armstrong Cork Company, Industrial Division, 7310 Dean Street, Lancaster, Penna.

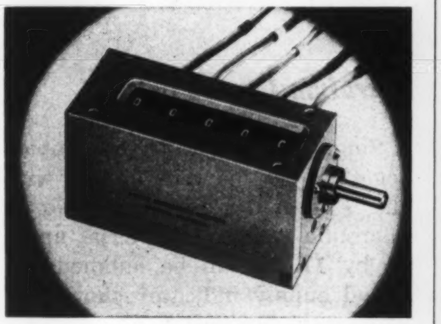


ARMSTRONG'S
DK-153 TAPE

ENGINEERING DEPARTMENT EQUIPMENT

Counters

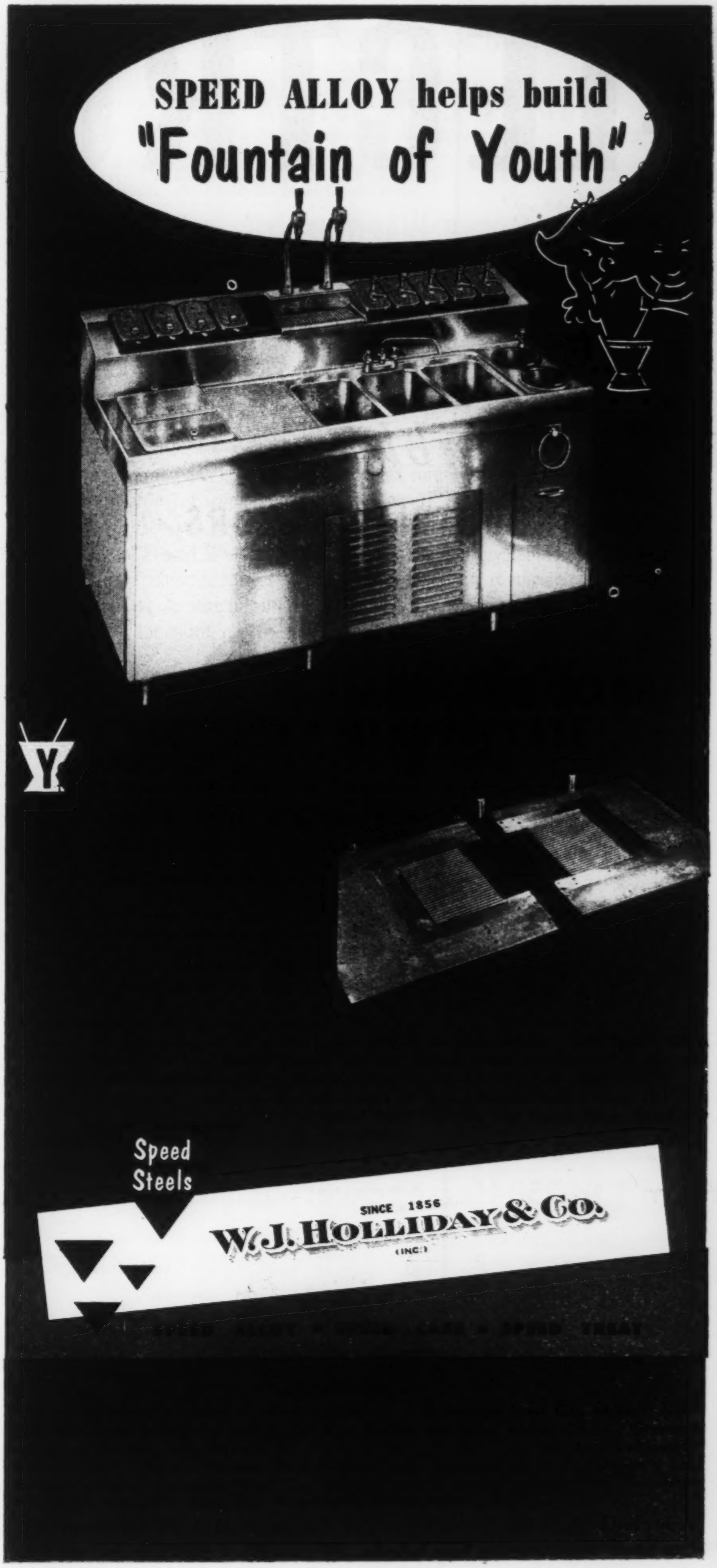
Digipot and Digicon decade counters record variables such as physical positions and servo actions, and totalize pulse inputs. Potentiometers on each digit-wheel of the Digipot provide a voltage division proportional to the number visually indicated by the mechanically coupled wheels. The Digicon has ten 10-ma contacts located around each decade of the mechanical counter wheels. Both units are available with either three or five decades. They operate in wide temperature ranges and withstand vibration up to 10 *g*. Made by **Wright Engineering Co.,** 180 East California St., Pasadena 1, Calif.



For more data circle MD-128, Page 257

Power Supply

Model 351 is one of a line of voltage or current stabilized power supplies which furnish dc power to equipment where unusually close performance tolerances, rapid recovery time and freedom from transient responses are required. Rated for 100 per cent duty cycle, regulation is held to ±0.1 per cent for line variations from 150-125 volts, and load variations from


SPEED ALLOY helps build
"Fountain of Youth"
Y
Speed
Steels
SINCE 1856
W. J. HOLLIDAY & CO.
(INC.)
SPEED ALLOY • SPEED CASE • SPEED TREAT

ELECTRO
Extra
DYNAMIC
Dependable

INDUSTRIAL MOTORS

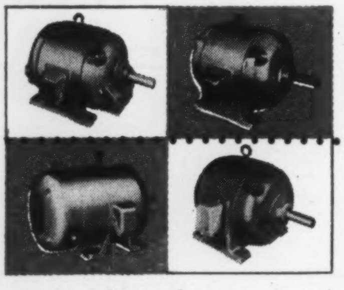
The WINDING is the HEART of the motor

Electro Dynamic

WRITE TODAY FOR CATALOGUE NO. 1062

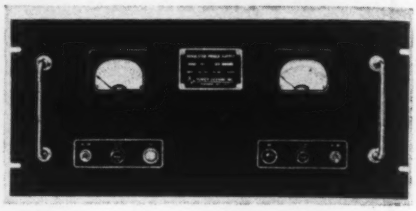
Every Electro Dynamic motor is built with
EXTRA INSULATION in stator slots and between phases
EXTRA IMPREGNATIONS and bakings of the wound stator
EXTRA HIGH-FREQUENCY TESTING of insulation between turns

From 1 to 250 Horsepower (N.E.M.A. STANDARDS)


One-piece cast iron frames.
Extra large "free-flo" air channels.
Permanently aligned cast iron brackets.
Liberal size grease lubricated bearings.

Also a complete line of Direct Current motors and generators

ELECTRO DYNAMIC
DIVISION OF GENERAL DYNAMICS CORPORATION
BAYONNE, NEW JERSEY



zero to maximum output current ratings; ripple and noise level is less than 1mv; internal impedance is less than 0.4 ohm; recovery time for instantaneous application of full load from a no-load condition is less than 8 milliseconds; stability is within 0.5 per cent per day. Operating range is 150-350 volts dc with a load of 0-150 ma maximum. It has a standard 19-in. rack panel, 8¾ in. high with a maximum depth beyond the panel of 9¼ in. Made by **Power Designs Inc.,** 119-22 Atlantic Ave., Richmond Hill 19, N. Y.

For more data circle MD-129, Page 257

Microfilm Camera

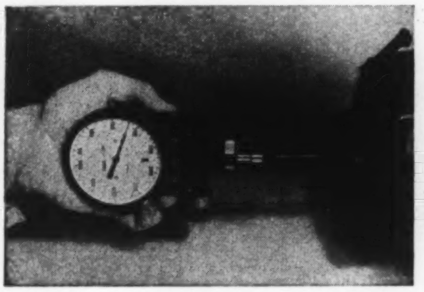
Single pages or pages stapled together can be microfilmed with the Film-A-Record Model No. 4 microfilm camera. Material up to 11 by 17 in. can be handled. A visual supply indicator shows the amount of film left in the camera, and an audible signal warns the operator when the film has been loaded improperly, when the take-up reel is full, or when the film fails to advance properly. A foot switch controls the operation of photographing and advancing the correct amount of film. The ma-

chine can be operated at speeds up to 1500 exposures an hour. Made by **Remington Rand Inc.**, 315 Fourth Ave., New York 10, N. Y.

For more data circle MD-130, Page 257

Tachometer

This portable instrument checks the revolutions per minute of motors, machinery, revolving shafts, etc. The rubber tip is pressed against the revolving shaft, and the number of revolutions per minute is read directly from the dial. It measures speeds from 40 to 50,000 rpm. Made by **Montgomery & Co. Inc.**, 53 Park Place, New York 7, N. Y.



For more data circle MD-131, Page 257

Magnetic Pick-Up

Model 3010-HT is a small electrical impulse generating device that converts mechanical motion to electrical energy while operating at temperatures as high as 500 F. It generates usable output voltages ranging from zero to 28 v at frequencies up to 75,000 cycles per second. Operating without physical contact or "loading" when mounted near any moving magnetic material, it generates a voltage output proportional to the rate of motion or speed of any metal object with magnetic properties. It may be actuated by the keyway in a shaft, the teeth of a gear, spokes of a wheel, a slot in the rim of a wheel or shaft, a screwhead or pin on a moving part, or any vibration or displacement of magnetic ma-

(*Continued on Page* 300)

AMERICAN CHEMICAL PAINT COMPANY

AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet

Subject: HOW GRANODRAW PHOSPHATE COATING FACILITATES COLD EXTRUSION OF STEEL

INTRODUCTION

By phosphate coating steel, prior to cold working it, extrusion, drawing, and other forming operations are greatly improved. In fact, it is the protective zinc phosphate coating that makes for the successful cold deformation of steel.

The tremendous pressures that most forming operations require produce extremely high frictional contact between die and metal. Without a protective coating, excessive galling (welding) of dies, breakage of tools, and unduly short die life will result. The combination of a non-metallic crystalline phosphate coating with an adsorbed lubricating film, possesses a low coefficient of friction while maintaining its stability under extremely high deforming pressures. This combination, therefore, greatly minimizes the aforementioned tool difficulties.

THE COLD EXTRUSION OF GENERATOR FRAMES

Cold extrusion is now being used advantageously in the manufacture of high production generator frames. This operation is facilitated by careful preparation and proper coating of the frame blank which is made from SAE 1010 open hearth plate steel.

After wheelabrating to remove the scale, the blank is rolled up and then fed automatically through a six stage dip wheel type washing machine which cleans the surface and applies the coating. The frame is then fed into an extrusion press where the wall thickness is increased on one end and reduced 47.5 percent on the other end. This operation produces concentric frames of uniform thickness and correct dimensions.

The Granodraw coating produces the proper surface to receive the lubricant by furnishing an extremely adherent film with the proper crystal size and continuity of coating required to insure maximum adsorbsion and tenacity by the lubricant. The lubricant, Montgomery DF 1101, is a combination of titre alkali soaps and resins. It is a powder which when dissolved in water and redeposited on the phosphate coated work piece, produces the necessary surface for subsequent operations. This film is dry and considerably less hydroscopic than similar coatings of the soap type. The concentrations of both the Granodraw and DF 1101 are maintained by simple chemical analysis.

PROTECTIVE COATING SEQUENCE

Stage	Operation	Chemical	Time	Temperature
1	Load and unload			
2	Cleaning	Tri-sodium phosphate and soda ash	1 Min.	180° F
3	Water rinse		1 Min.	180° F
4	Zinc phosphate coating	"Granodraw"*	4½ Min.	165° F to 180° F
5	Water rinse		2 Min.	180° F
6	Lubricating	H.A. Montgomery lubricant DF 1101	4½ Min.	190° F

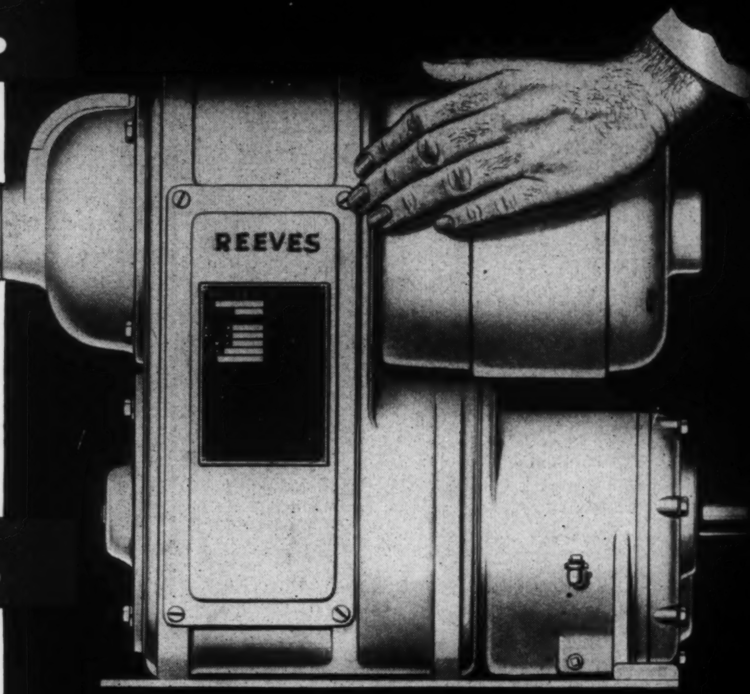
*Trade Mark of the American Chemical Paint Company

CHEMICALS ACP PROCESSES

REEVES
Variable
Speed Drives

Any
you

with Motodrives . . .



● Small, compact, but *rugged* REEVES Fractional hp Motodrive gives increased output, greater efficiency and uniform production from your light machinery. In one space-saving unit encased in newly-designed, lightweight housing, REEVES Fractional hp Motodrive brings you: A standard NEMA face-mounted motor and REEVES time-tested speed varying mechanism for positive, accurate, speed changes without stops. Horizontal units are 9⅝″ high; vertical units 16⅞″ high. Available in ¼, ⅓, ½ and ¾ hp capacity with speed ratios up to 10:1.

For heavier duty, *integral* hp REEVES Vari-Speed Motodrives are available with capacities to 30 hp and with speed ratios from 2:1 through 6:1.

with Flexi-Speed Drive . . .

● For extreme versatility in operation and application, *simplicity* and *economy* in installation and *speed range of 8:1,* choose REEVES *new* Flexi-Speed Drive. Essentially a Motodrive without housing, REEVES Flexi-Speed Drive is a compact combination of constant speed disc assembly with shifting mechanism, mounted on the drive shaft; variable speed pulley mounted on the driven shaft; and double-cog belt linking the two. Converts any standard motor into a highly flexible variable speed drive. Easily adapts for right angle applications. Available in ½, ¾ and 1 hp capacities.

with Motor Pulleys . . .

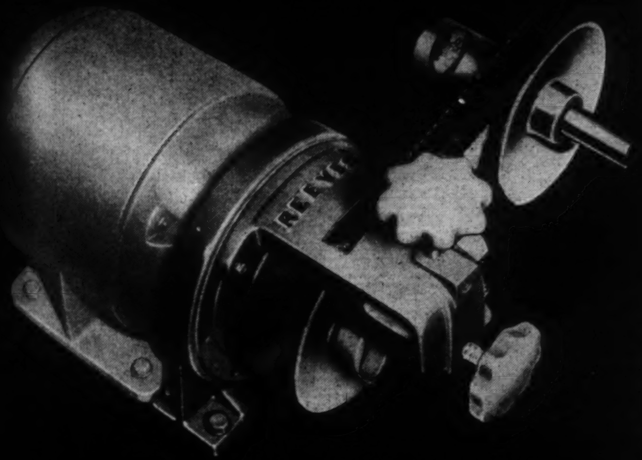
● Boost your production in light or heavy duty work applications by converting your fixed speed motors to infinitely variable drives with REEVES Vari-Speed Motor Pulleys . . . the simplest, most economical way known to industry.

Two styles available—Vari-Speed Junior, for use with Standard A or B section V-belts, carrying loads up to 1½ hp; Standard Line, using REEVES Vari-Speed belt, sizes up to 10 hp. Speed ratios as high as 4:1 inclusive.

REEVES VARI-SPEED MOTOR PULLEY

speed need

-anywhere you need it! fractional to 87 hp

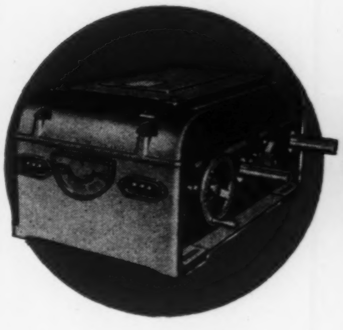


REEVES FLEXI-SPEED DRIVE

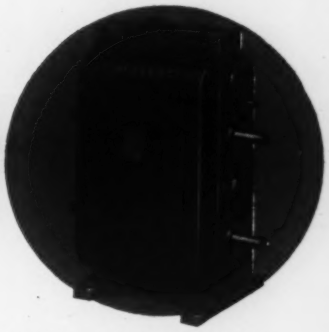
Other Units in the Complete REEVES Line!

VERTICAL MOTODRIVE

HORIZONTAL MOTODRIVE



VERTICAL TRANSMISSION



HORIZONTAL TRANSMISSION

REEVES VARI-SPEED JR.

REEVES offers many different methods of control for changing speeds—either manually or automatically—handwheel, which is standard, electric, or completely automatic.

For machines you buy or build, obtain *all* the benefits of stepless speed adjustability by specifying REEVES Drives. Send for catalog, No. H87-1-3N.

REEVES

SPEED CONTROL

REEVES PULLEY COMPANY • COLUMBUS, INDIANA

Recognized leader in the specialized field of variable speed control

No. 1 - Precision Operations in the Manufacture of ACME Chains

The most improved types of heat treating and carburizing furnaces have been installed to give Acme roller chain pins and bushings a glass hard bearing surface for greater strength and longer life expectancy.

ACME CHAINS are made for STRENGTH and DURABILITY

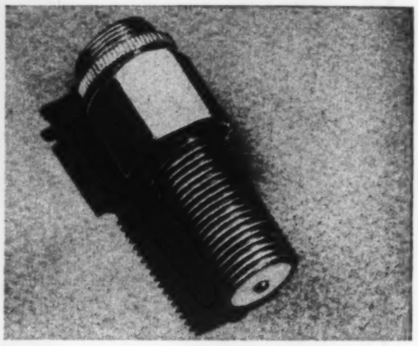
All parts are made from carefully selected analysis of steels. The selective steel analysis for each chain part is based on bringing out the best physical qualities obtainable. All parts subjective to articulation have hard wear resistant surfaces to promote eminent life expectancy. The side plates or links which act as connecting members for the articulating parts are heat treated and tempered to insure great strength and ductility.

Write Dept. 6A for new illustrated 76 page catalog on use and application of roller chains and sprockets.

Acme Chain Corporation
HOLYOKE
MASSACHUSETTS

(Continued from Page 297)

terial in the field. For indicating rpm, operations, cycles, angular and linear motion, the device actuates electronic counters, serves as a tachometer when used with a voltmeter, and provides synchronizing voltage for an oscillograph, among other uses. Made by **Electro Products Laboratories Inc.**, 4501 North Ravenswood Ave., Chicago 40, Ill.



For more data circle MD-132, Page 257

Thermal Test Chamber

Available in capacities from 1 to 4 cu ft, this unit operates at temperatures from −130 to 250 F. Temperature control can be either manual or automatic. Rate of temperature drop can be varied to suit requirements. An automatically controlled, waterproof, explosionproof heater provides the high temperature cycle. The test chamber is equipped with a fan

Diversatility rides again in the new COMPLETE line of SPEED KING Valvair Solenoid Pilot Operated Control Valves

VALVAIR CORP. AKRON, OHIO

Valvair Speed Kings are small, light in weight, with a speed of 600 cycles per minute, and proven capable of 20,000,000 cycles and up.

The New Valvair Speed King line is complete — 3-way, 4-way, and 4-way-5-port (2-pressure), foot-mounted or sub-base manifold mounted; pipe sizes — ¼", ⅜", ½", ¾", 1". *Complete* — to fit almost innumerable applications. A precedent-breaker in size, weight, speed and endurance. Only one moving part. Non-corrosive materials throughout. Solenoid and pilot valve parts are totally enclosed, but easily accessible. *Get all the facts!*

VALVAIR CORPORATION Affiliate: Sinclair-Collins Valve Company
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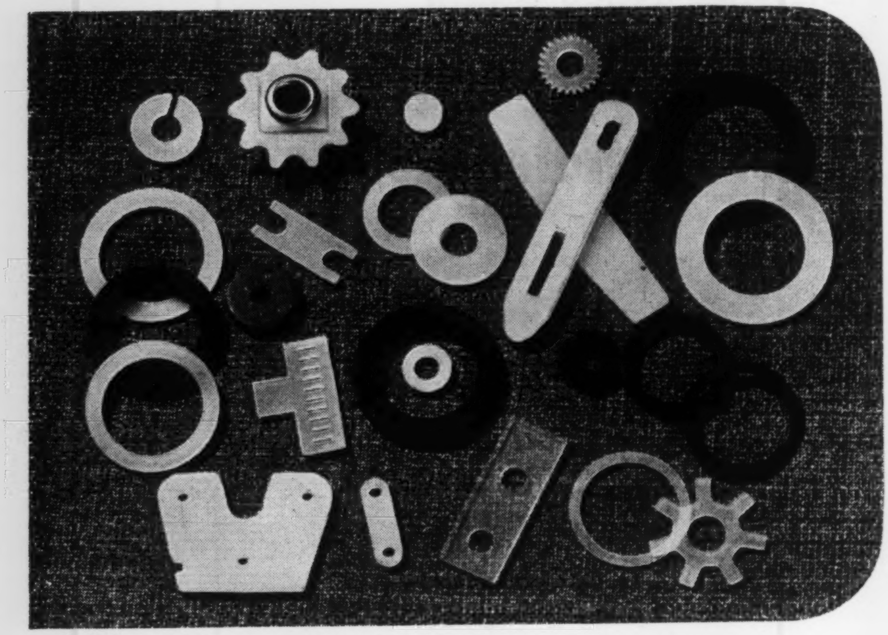
REPRESENTATIVES IN PRINCIPAL CITIES

Rely Upon Valvair DIVERSATILITY

Ask for Bulletin "D-10".

REDUCE THE COST OF NYLON PARTS



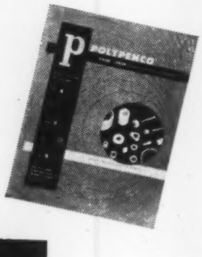
...BY BLANKING THEM FROM

POLYPENCO® NYLON STRIP

A wide variety of nylon parts can be blanked from POLYPENCO strip. Standard metal-working punch presses and feeding methods are used. In addition, production rates can be as high as 600 pieces per minute for lower unit costs. Standard strip sizes permit parts as thick as .125″ and as wide as 4″.

Use of POLYPENCO nylon strip eliminates costly delays in tooling and practically eliminates tooling cost. You get assurance of uniform high quality output, too. Every coil of stock undergoes rigid tests for constant properties and uniform dimensional tolerances.

Write today for sample parts blanked from POLYPENCO strip. A new 4-page bulletin on POLYPENCO nylon and other non-metallics is also available upon request.



POLYPENCO NYLON

nylon and teflon* other non-metallics / *stock shapes, finished parts*

also available to your specifications

The POLYMER CORPORATION of Penna. • Reading, Penna.

*trademark for Du Pont tetrafluoroethylene resin

In Canada: C-H Engineering Company • Montreal • Toronto

for controlled air flow and uniform temperature distribution. A temperature recorder is also provided. Compact, the unit occupies 7½ sq ft of floor space. Made by **Sub-Zero Products Co.,** Reading Rd. at Paddock, Cincinnati 29, O.

For more data circle MD-133, Page 257

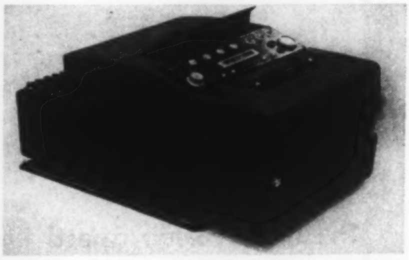
Soap Eraser

Neater, more efficient operation and longer life are claimed for a new vinylite resin base eraser. It resists crumbling and removes pencil marks thoroughly. It also resists the effects of aging. Supplied in packages of four by **Richard Best Pencil Co. Inc.,** 100 Waverly Ave., Springfield, N. J.

For more data circle MD-134, Page 257

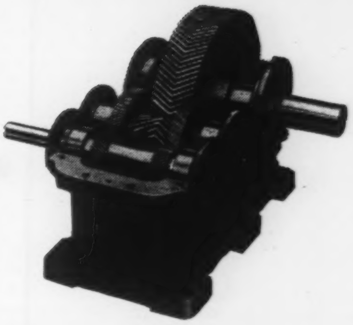
Recording Oscillograph

Designated Type 5-119, this instrument accurately records 50 active data traces on 12-in. paper or film. Making records 250 ft in length at speeds from 0.10 to 100 in. per second, it provides new safety and warning devices to prevent data loss. Record speeds are changed without the use of tools through interchangeable gears, access to which is gained when the magazine is removed. A jump switch increases record speed ten times without stopping the oscillograph, spreading complex wave forms to allow quicker, easier and more detailed interpretation of data. Narrower paper can also be used in the adjustable magazine. Timing lines are adjustable to full record width or 1 in. at borders at intervals of either 0.01 or .10-second between lines. Frequen-



HOT MIX non-stop!
JONES
JONES

One of two new Allis-Chalmers kilns at Basic Refractories Inc. Maple Grove, Ohio plant. Dual drives engineered by Allis-Chalmers Mfg. Co. and W. A. Jones Foundry & Machine Co.



Driving a non-stop giant size rotary kiln calls for PLUS PERFORMANCE

That's why Basic Refractories selected JONES HERRINGBONE GEAR SPEED REDUCERS to drive two new rotary kilns — the largest in the world's refractory industry — at their Maple Grove, Ohio dolomite processing plant.

Operations at Basic are continuous. In processing, dead burned dolomite must be constantly *ON THE MOVE* — a drive failure could result in serious damage from the hot mixtures in the kiln.

Naturally, Basic Refractories' engineers took utmost care in the drive component selection for this important application. And, naturally, they chose JONES HERRINGBONE GEAR DRIVES because of their proven ability to stay on the job and take the 'round-the-clock, day-in and day-out punishment of continuous operation.

Giving PLUS PERFORMANCE under these and similar conditions is nothing new for any type Jones Speed Reducer — all are recognized and accepted throughout industry for all sorts of applications demanding rugged dependability, maximum capacity and quiet, smooth, power transmission.

BIG DRIVES — SMALL DRIVES — You may not have a giant kiln to drive; but when you have a power transmission job, big or small or anything in-between, your best answer is JONES . . . it has been for over 60 years.

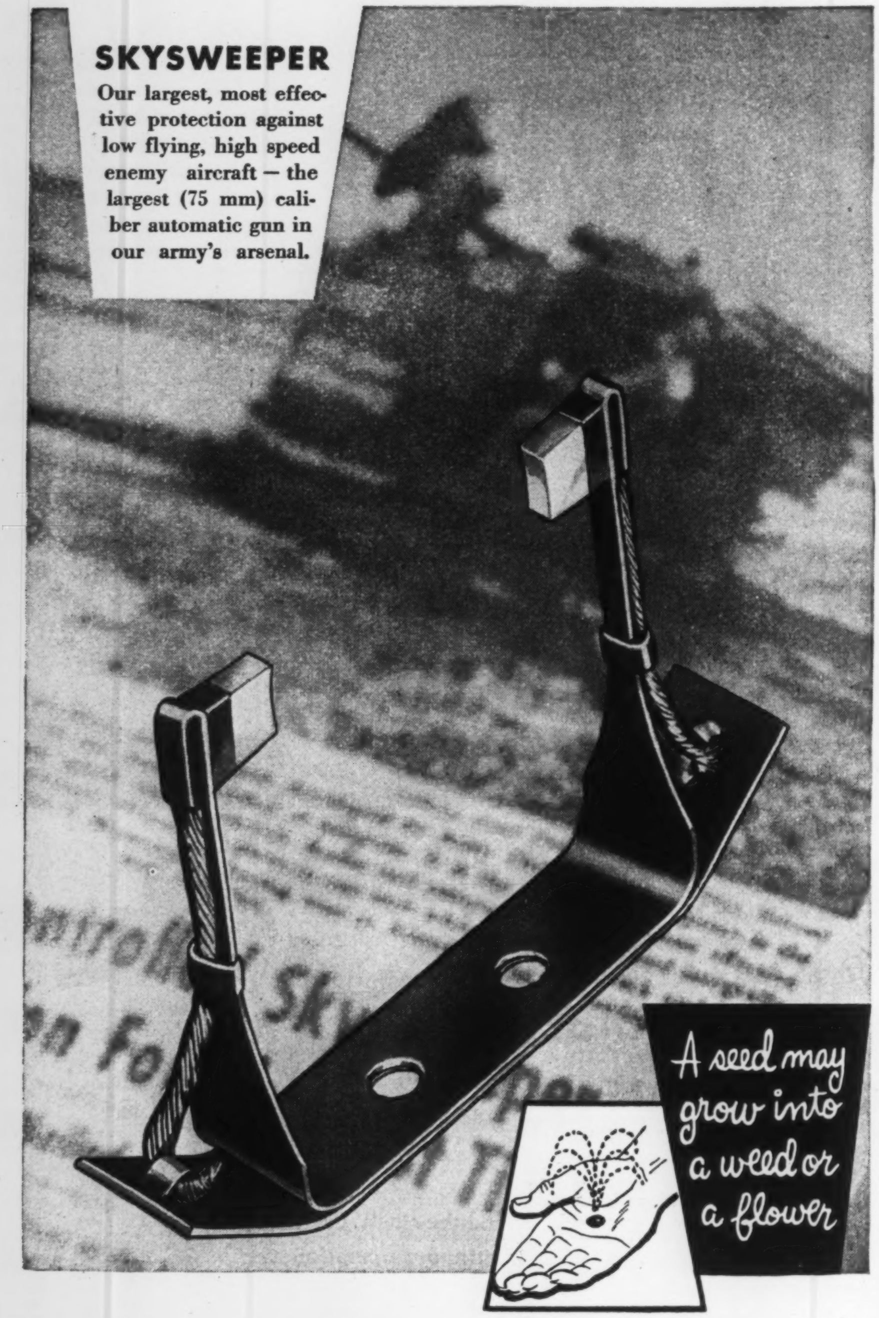
W. A. JONES FOUNDRY & MACHINE CO. **4413 Roosevelt Road, Chicago 24, Illinois**

Ask for Catalog 70

Since 1890 . . . In the Service of Industry

Jones

[illegible]
[illegible] • [illegible] • V-BELT SHEAVES
ANTI-FRICTION PILLOW BLOCKS • [illegible]



SKYSWEEPER

Our largest, most effective protection against low flying, high speed enemy aircraft — the largest (75 mm) caliber automatic gun in our army's arsenal.

—and a CARBON BRUSH can operate or wreck a great Skysweeper . . .

A tiny brush in the huge program of national defense—but how powerful for safety or ruin! Contacts and brushes developed, like this one, by the Superior technical staff hint at our readiness to ferret out *your* exact requirements—to work long and closely with you as your needs demand.

SUPERIOR CARBON PRODUCTS, INC.
9115 GEORGE AVENUE, CLEVELAND 5, OHIO

SCP
SUPERIOR CARBON BRUSHES
"Since 1919"

cies from 10 to 500 cycles per second may be viewed as wave forms on the ground glass screen by using the variable speed scanning system. Timing lines also appear at the center of the screen. Trace identification is provided by interrupter pins producing a 0.032-in. gap every 15 in. on each trace. Dimensions are: height, 13¼ in.; width, 15½ in.; length, including magazine, 27 11/16 in. Made by **Consolidated Engineering Corp.**, 300 North Sierra Madre Villa, Pasadena 8, Calif.

For more data circle MD-135, Page 257

Pulse Generator

CONFLUXER
WANG LABORATORIES

"Confluxer" produces constant charge pulses, triggered by the behavior of the input voltage to the device. A pulse is produced when the instantaneous voltage of the input initially exceeds a fixed value, the device being reset by the return of the voltage below the critical value. Used as a frequency meter, electronic tachometer or as a digital to analog converter, it is also suitable for pulse generation, microsecond pulse generation from slowly varying input and pulse amplitude discrimination. Output has a linearity of 0.2 per cent. Input waveform with a rise time as slow as 0.1-sec insures proper operation. Output pulse rating is 200 volt-microseconds. Minimum output load is 2500 ohms. Pulse duration is approximately 3 microseconds. Made by **Wang Laboratories**, 296 Columbus Ave., Boston 16, Mass.

For more data circle MD-136, Page 257

Stress Relief

HE HAS NOT completed his series of detailed analyses of different types of engineering personnel, but this month J. P. Henderson elevates his sights and takes aim on management. His message, however, is food for thought at all levels.

Mulish Managers

In looking askance at people (and I seem to be doing it continuously) let's not overlook management.

One of the common errors of management is *its failure to recognize its own kind.* This same quality in horses resulted in the mule. In management it results in inept and poorly qualified department heads.

Selecting managerial talent is a difficult job. There are probably all sorts of tests for the determination of this ability, as there seem to be tests for everything nowadays. But at such tests, too, I look askance although I am willing to be convinced that there might exist some yardsticks for identifying managerial ability.

One of the most common (and disastrous) methods of selecting a department head or manager is to promote the man who made good in his job as a subordinate.

"What's this? You shouldn't promote the man who has made good? Tommyrot!"

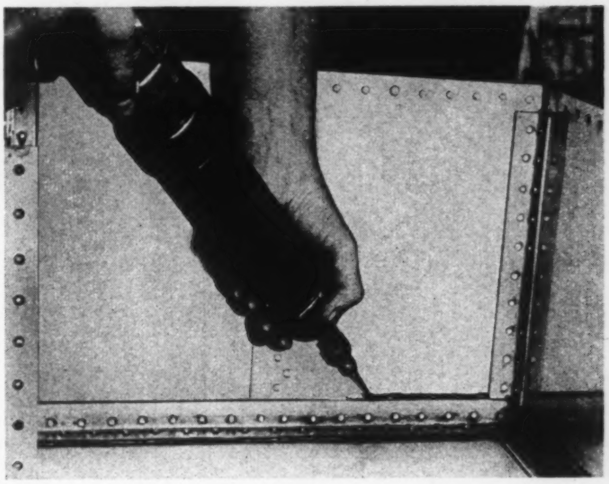
Not at all, I say. Let's consider some cases.

You have a draftsman who makes the finest, cleanest drawings in the least possible time. He's good; but does it follow that he is, therefore, qualified to be chief draftsman? As such, he might never make a drawing.

A designer has good design ability; his work is reliable and his judgment is good. You consider him outstanding in the entire engi-

(*Continued on Page* 310)

SPECIFY Thiokol® LIQUID POLYMER LP-2
for CRITICAL SEALING JOBS



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Because of these properties, "Thiokol" LP-2 compounds are specified for sealing airplane wing tanks as pictured. It provides the required combination of properties and dependability in this critical application.

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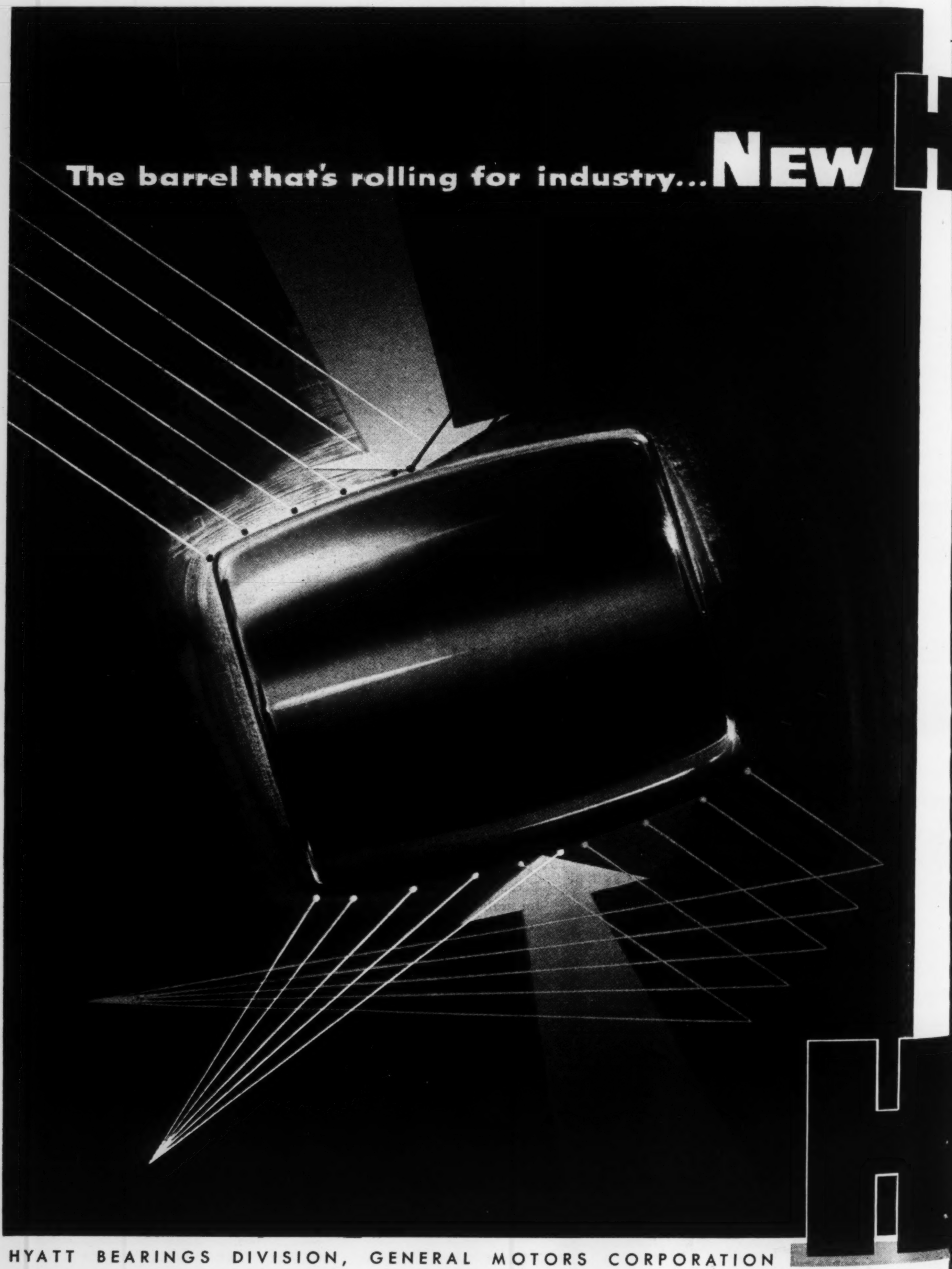
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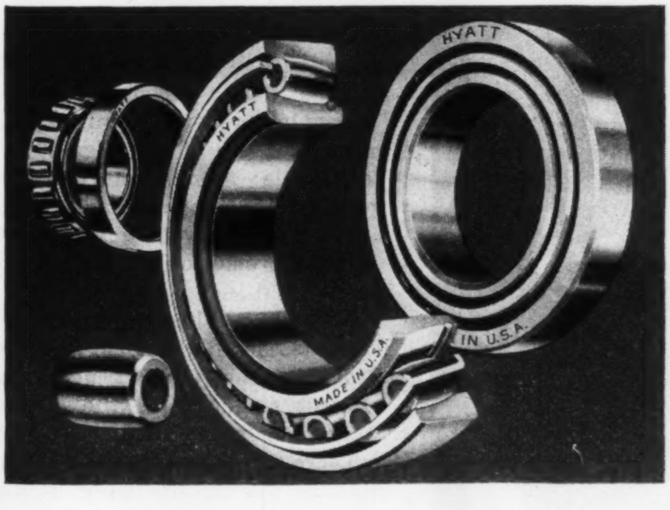
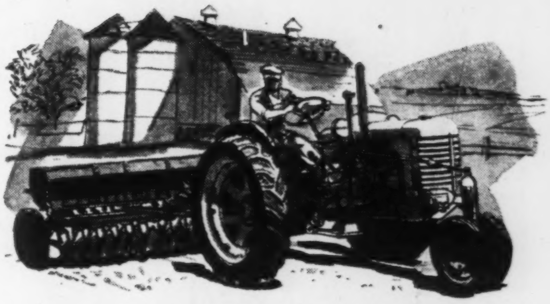
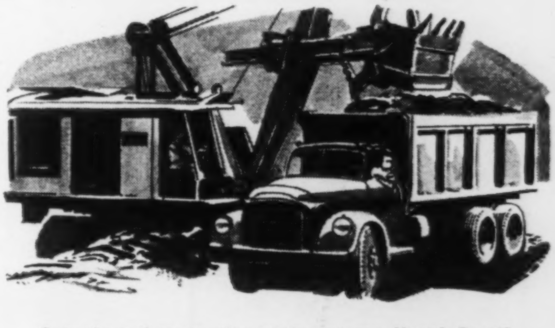
Expensive? *Not at all!* Advanced manufacturing processes—plus the facilities of one of the newest and finest bearing plants in the world—make the initial cost far lower than you would expect! . . . For full information on this newest solution to the friction problem, write to the address below.

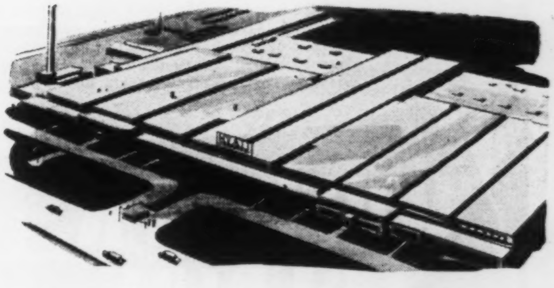




Self-aligning action makes the Barrel Bearing ideal for tractors and farm implements. Over many years, its durable, dependable performance has been established in a wide range of these applications.



In trucks and construction equipment, too, Hyatt's Barrel Bearing operates with full efficiency under conditions of heavy, multiple-direction loading. Unique roller and race design distributes the load over large areas of contact.



Hyatt's new plant, in Clark Township, N. J., is among the most modern in the world. New equipment makes possible advanced manufacturing processes, and research facilities are the finest in the bearing industry.

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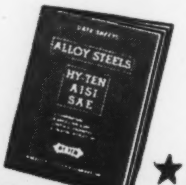
Write today for your FREE COPY of the Wheelock, Lovejoy Data Book, indicating your title and company identification. It contains complete technical information on grades, applications, physical properties, tests, heat treating, etc.



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Stress Relief

(*Continued from Page* 307)

neering department, but does that mean he will be a good chief engineer?

You have another designer who is the most ingenious fellow imaginable. He eats and sleeps mechanisms and gadgets. Would you promote him to head of a department?

Now the whole difficulty is that there are plenty of presidents and general managers who apparently would answer "yes" to these questions and would promote such people. Whereupon we have new department heads who find that their time is taken up with conferences involving policy, personnel problems including hiring and firing, outside visitors, planning programs and matters of departmental and interdepartmental organization. Rarely do they have a moment for working on those details on which they established their reputation for being expert, nor indeed are there usually any means by which they could do such a detailed job again.

Occasionally such a man revamps his interests, applies himself mightily to his new problems until he reaches some degree of aptitude and becomes a successful manager. But more often, it has been my observation, he fails. Sometimes this failure takes the form of a gradual easement into his old detailed work with the attendant neglect of the broader duties of management.

Now let's repeat the initial statement and see if it sounds more reasonable: A man who has made good on his job as a subordinate is not necessarily the logical candidate for promotion to a managerial position.

Actually it takes more than that. He must have additional qualities. Probably the most general and briefest summary of the requirements is a "broad view."

There are some ironical elements in this matter of being a high caliber person capable of promotion. In some cases, early environment and training produce a young man who impresses you at once as being capable of going places—given half a chance. But if he is hired to do a job—and does it very conscientiously and well—he may

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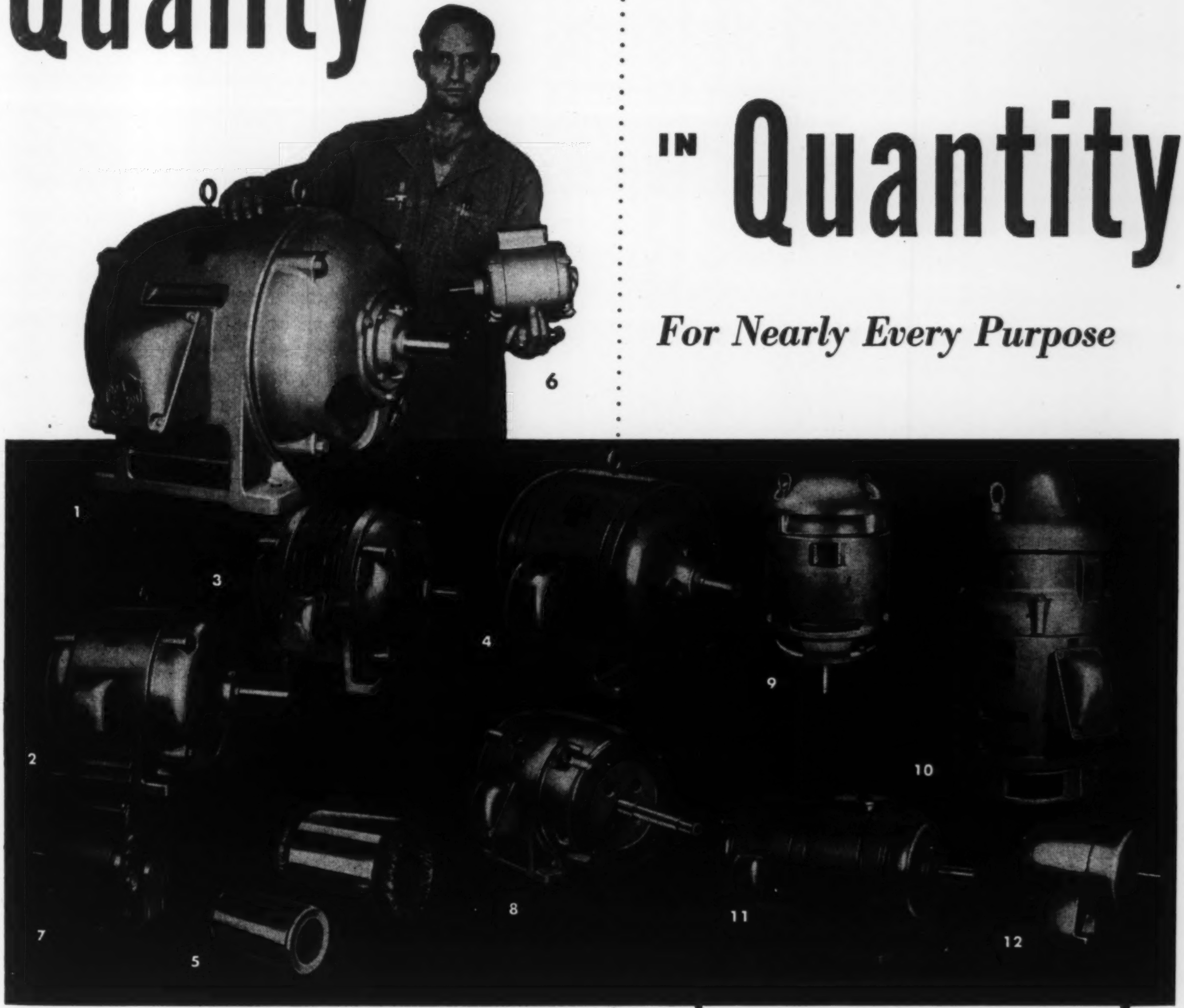

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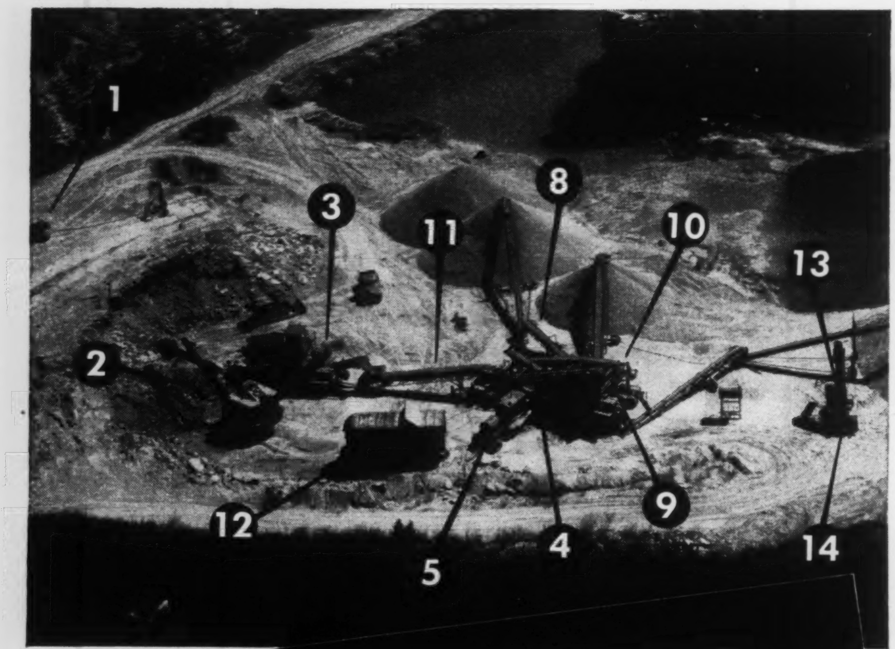

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14 Drives in action!

Typical example of powered equipment in modern industry is Stoneridge Limestone Company's aggregates plant near Rochelle, Ill. And typical example of Twin Disc's *complete range* of Friction and Hydraulic Drives is the aerial photograph above of the Stoneridge operation. Nine of the Twin Disc Drives were built-in by the original equipment manufacturer . . . five were installed by Stoneridge.

Whether built-in or added for extra performance, Twin Disc Drives have the *right design, construction and capacity.* See your Authorized Twin Disc Hydraulic Dealer.

And here they are . . . count 'em!

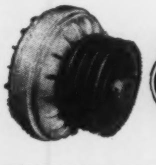
Twin Disc Spring-Loaded Clutch on International-powered LeRoi Compressor (1).

Twin Disc Friction Power Take-Offs on Cummins-powered Bay City Shovel (2); Caterpillar-powered Universal Jaw Crusher (3) and Universal Hammer Mill (4); and on Minneapolis-Moline-powered Pioneer Roll Crusher (5).

Twin Disc HYDRO-SHEAVE® Drives on Stoneridge-built horizontal conveyor (8); Simplicity Vibrating Screen (9); Pioneer Vibrating Screen (10); and Stoneridge-built Conveyor (11).

Twin Disc Hydraulic Coupling on Hercules-powered generator plant (12).

Twin Disc Friction Clutches (two each) on Nelson P-10 Loader (6, 7; not shown); and Nelson P-11 Loader (13, 14).



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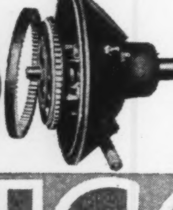

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Stress Relief

fail to gain that very broad knowledge of his job and the organization that makes him more desirable for promotion. In many cases, he learns more (and develops) through giving attention to items in his daily work for which he was not specifically hired.

Managerial ability is not only difficult to recognize, but it's even difficult to describe. Think of the times when a small group are discussing someone who is outstanding as an executive or leader and note how they grope for words, "He is broad gage." "He has that spark of leadership, or something." And so on. It is with such inept terms that we try to define the qualities that measure a supervisor or manager.

I cannot define managerial ability any better than the average, but I have known persons with qualities which made them unsuitable for leadership. In the near future, let us examine some of these species.

—J. P. Henderson

They Say . . .

"A popular concept of the inventors is that of a visionary long-haired, bleary-eyed, impractical, romantic figure. To get a survey opinion as to the nature and extent of this difference, several hundred questionnaires were sent to patent attorneys, to research and engineering directors, and to many of the Country's most prominent inventors. The questions were: 'Are inventors different from non-inventors? what are the mental characteristics of the inventor?'

"The most frequent characteristics mentioned in the answers were remarkably alike. Inventors are unusual and different chiefly in their perseverance, imagination, originality, power of analysis and in having an observing, sensitive and artistic temperament. Many inventors themselves excel in one or another of the fine arts. Invention and creative work of artists are thus functions and acts of the same mind, the exercise of the creative instinct and ability."
—Hal F. Fruth, *consultant and physicist, Hal F. Fruth & Assoc.*

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From conventional light duty thrust bearings in 1916, Aetna's versatility has grown to include all-type-all-duty ball thrust bearings, roller bearings and vital parts spanning an incredible range of industrial applications.

It's worth remembering—Aetna's diversified usefulness to industry—Aetna's reputation of producing to the stiffest tolerances known to the industry.

If you are having bearing or parts troubles—if you need a more versatile, more dependable supplier, consider Aetna. Your satisfaction is assured by the fact that 80% of our business comes from firms we have served for 20 or more of our 37 years. Write! Just state your problem, send your prints, or ask that a near-by representative drop in. No obligation. Aetna Ball and Roller Bearing Company, 4600 Schubert Avenue, Chicago 39, Illinois.

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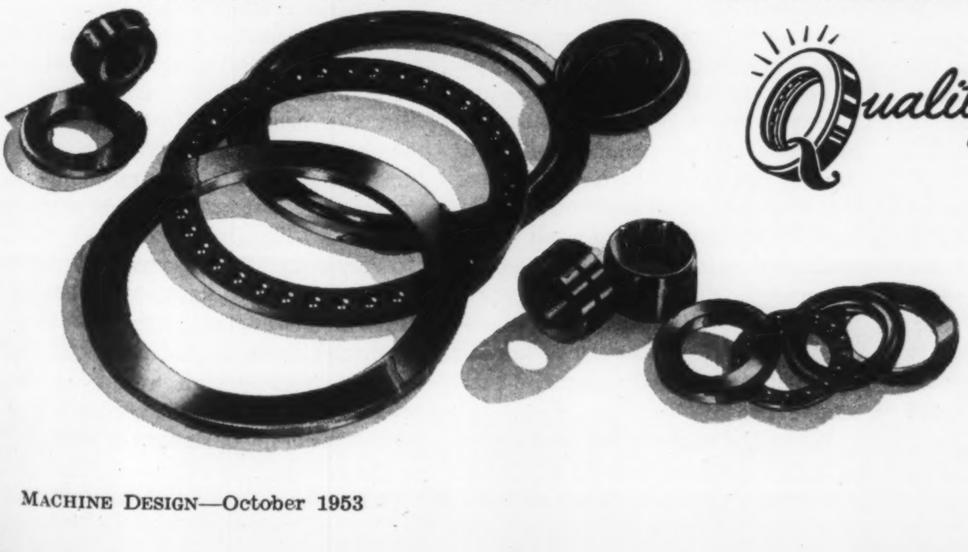


PRODUCTIONIZING NEW MATERIALS

DESIGN ABSTRACTS

Two diverse approaches which attack the problems of putting new materials to work in design

Developing Design Data

By Howard W. Benjamin

Group Engineer
Lockheed Aircraft Corp.
Burbank, Calif.

NEW materials offer a real challenge to industrial know-how. A particularly dramatic example was the recent introduction of titanium onto the aircraft scene. How this material was accelerated into a production scheme illustrates a logical approach based on sound engineering practice.

Necessity of obtaining basic fabrication data on a new material before releasing it for design and production requires an orderly procedure for examination of the material by standard basic tests and the transmittal of experimental data to the affected engineering and manufacturing groups. The designer realizes that producibility and serviceability of a new material is equally as important as the initial weightsaving and structural advantages claimed by the producer. Management, on the other hand, knows that it costs money to put a new material into production and is willing in general, to finance its share of a sound program to investigate thoroughly the structural and producibility aspects of the material.

A complete analysis of a new metallic material includes the laboratory work necessary to prove out the producers' claims and furnish the additional information on properties required by structures and methods development groups. Design criteria on which to base a structural analysis are not enough for the designer; he must also have complete design data on formability, weldability, and machinability in order to design for producibility. Forging, extruding, and casting properties must be considered and evaluated for producibility as well as for structural advantages.

The nonmetallic, or loosely referred to as plastic, materials must also undergo a careful scrutiny to obtain complete fabrication data for the designer. In both types of materials, metallic and nonmetallic, the fabrication problem must be coordinated with production capabilities and the necessary process specifications and manufacturing standards compiled to assure a smooth flow of processing through the various shops.

When the engineering and manufacturing groups have sufficient information to give a green light to the new material, the consumer becomes another obstacle to overcome. Naturally the consumer is interested in serviceability; how this material stands up in all types of weather, operating conditions and everyday servicing wear and tear. These questions can partly be answered in the laboratory, but nothing is more convincing than a sample part operating under actual conditions in an easily accessible spot that can be readily inspected.

Basic Tests: An outline of the basic tests required and a description of the types of data necessary for design and manufacturing will help to explain the cost, time span, and complications involved to productionize a new material.

The standard test data described in the following resume is not by any means the complete data required for production, but rather the basic information necessary to make a preliminary comparison of a new metallic material to other known materials. These data point out the need for more exhaustive study on phases that are peculiar in their reactions to tests or do not respond to current methods of fabrication.

PHYSICAL PROPERTIES: A spot check is made of available producer data in regard to physical, chemical, and temperature properties to satisfy basic design needs. Additional testing must be continued to develop complete design criteria.

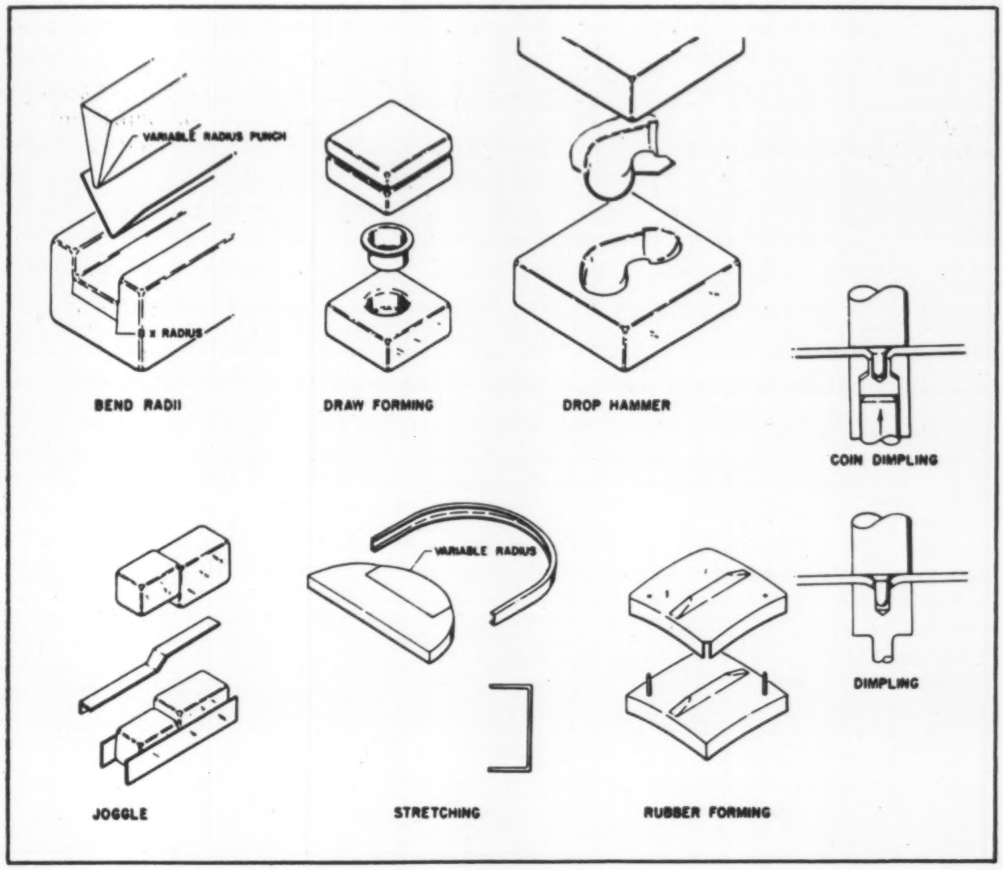


Fig. 1—Standard forming tests for determining characteristics of new materials

Tests on several mill runs and shapes are required to obtain the variation in physical properties due to different reduction of the material and mill practices in producing shapes. Some of this information is available from the producer but is usually based on experimental runs and does not represent the statistical data obtained by testing several production mill runs. This type of testing continues until a government material specification is available.

FABRICATION: The effect of fabrication operations on the material is tested for structural data. The following operations are included.

Machining: Samples of a new material are put through the following conventional machining operations: (1) Cutting, such as slab milling, straddle milling, end milling, slotting, turning, boring and threading; (2) Drilling; (3) Reaming; (4) Tapping; (5) Grinding. On each of these operations data are obtained for comparison with standard materials.

Part costs are an important consideration and can be analyzed by comparative floor-to-floor time on any of the machine operations. Tool life compared with other materials becomes a part of machining costs. If conventional tools will not cut a new material, special tools must be checked and their costs noted for each operation in which they are required. The effect of machining a material is checked by evaluating the percentage of rejections caused by warpage, surface cracks, and any other ill effects that will cause scrappage of the part, additional surface treatment or straightening.

Machining on present production equipment is also a consideration as some of the new materials now being evaluated will require heavier equipment or, in some cases, higher cutting speeds for satisfactory surface finishes and economical machining.

Forming: Standard forming tests as illustrated in *Fig.* 1 give comparative data to other known materials. Details of these tests are given as follows:

1. Bending on a standard brake tool with varying radii gives data on minimum bend radii.
2. Joggling of angle sections of varying depths and transition lengths, both hot and cold, pro-

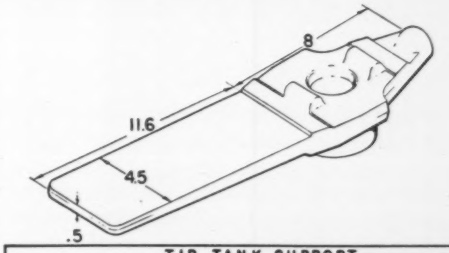


Fig. 2 — Cost and weight data for analysis of forging characteristics of a new material

TIP TANK SUPPORT

DESCRIPTION	8630 STEEL (ACTUAL)	NEW MATERIAL	
		PRODUCERS DATA	DATA FROM BASIC TESTS
COST OF FORGING STOCK	$ 0.10/LB.	$ 10.00/LB.	$ 13.00/LB.
MAT'L COST/ FORGING	$ 6.00	$ 195.00	$ 254.00
FORGING COST/ PART	$ 1.90	$ 5.70	$ 10.00
TOTAL COST OF FORGING	$ 7.90	$ 200.70	$ 264.00
MACHINING COST / PART	$ 130.00	$ 390.00	$ 500.00
TOTAL COST OF FINISHED PART	$ 137.90	$ 590.70	$ 764.00
WEIGHT SAVED PER PART		5.9 LBS.	5.9 LBS.
COST PER LB. OF WT. SAVED		$ 100.12	$ 129.50

duces comparative joggle data with other materials tested.

3. Drawing is evaluated by the use of a standard cupping die. All samples are gridded for measurement of the variations in elongation after drawing. Maximum draw depth is obtained for a depth to diameter ratio.
4. Stretching over a standard die with varying radii inserts produces data for elongation with grain and cross grain. Samples are gridded for measuring areas of elongation and are prepared with both sheared and polished edges to show tendency toward cracking. A one per cent prestretch is given to each sample to assure uniform properties before testing.
5. Drop-hammer parts evaluate complex forming characteristics. Parts can be formed at elevated temperatures, if necessary, to obtain best results. A grid is used to measure shrink and stretch areas.
6. Rubber forming on a standard die with a one-inch flange checks adaptability of the material to withstand a ten per cent stretch and eight per cent shrink. Variations in flange widths allow testing of stretch and shrink values from 0 to 20 per cent. Results of high temperature and high pressure forming are recorded.
7. Dimpled shapes and quality are checked with conventional and coin dimpling, both hot and cold. The pressure, dwell time and temperature are noted and compared with other similar materials.

Welding: Spotwelding integrity is tested by using single spot shear and tension tests. These tests are also used to establish maximum pile-up of material and compatibility of similar alloys. Consistency tests on 50 to 100 welds are normally run in panel form. Metallurgical examination is accomplished by cross-sectioning the center of the spot weld and observing for geometry and faulty structure.

Flashwelding specimens are prepared using tubing, bar, or plate stock. Tension and bend tests are used to check physical properties. Varying material thickness and diameters are checked for limitations in welding. Metallurgical examination of grain structure, flow, and defects are necessary to fully evaluate the method.

Fusion welding is checked for applications to the new material by producing panel-type specimens utilizing a particular welding method.

Testing of the weld area and affected area must be thoroughly analyzed by pull and bend tests as well as metallurgical examinations.

Forging: Comparative forging data to standard materials are obtained. The evaluation of metal movement will show the necessity for variations from standard forging techniques. Number of stages required to forge a part is an economic consideration. Metallurgical examination of cross-sections for quality shows up imperfections.

Castings: When a new casting material is introduced, it is necessary to develop specifications in regard to the strength of the material and its limitations for section thicknesses, flow of the material, and other data required for design criteria.

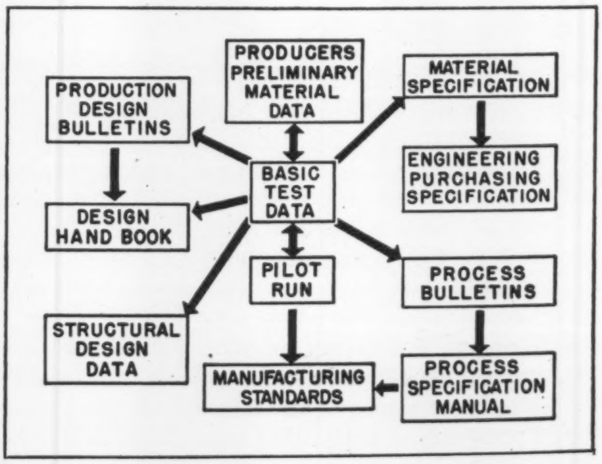
PROCESSING: Sufficient laboratory tests must be run on a material to prove its adaptability to standard processing operations such as: (1) Heat-treatment, (2) Cleaning, descaling, etc., (3) Surface finishing, (4) Metallic and nonmetallic coating. If standard processing operations are not suitable for the material, additional investigations are required.

QUALITY CONTROL: Inspection techniques to maintain quality control standards are investigated and recommendations made as to the type of material inspection required. Inspection tools such as X-ray, Magnaflux, Zyglo, Dy-Check, etc., are examined and if applicable, inspection standards are established. When present inspection techniques are not sufficient to maintain quality control, new equipment and techniques must be designed and developed.

Costs: The raw material costs and estimated production costs are important data obtained from the standard basic tests. It is natural to assume that the cost of the material will be reduced when production quantities are increased, and that the fabrication costs will be reduced with experience. The material producer can project the cost of the material to a point of anticipated usage and the manufacturer can project production costs by means of learning curves to a corresponding production quantity.

A material recently introduced to the industry offers an excellent example of the cost to reduce structural weight. In *Fig.* 2 is a cost analysis of a forged part which compares a new material to steel which it could replace at a substantial weight reduction. The preliminary machining costs given by the producer and the actual machining costs proven during the standard tests illustrate significant differences that cannot be minimized without developing a new method for removing metal or a new alloy that can be easily machined.

Parts Production: The best of new materials has no value to a manufacturer unless methods are developed for producing finished parts either on existing or on new equipment. Each new material requires extensive methods develop-


PRODUCERS PRELIMINARY MATERIAL DATA
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MATERIAL SPECIFICATION
BASIC TEST DATA
ENGINEERING PURCHASING SPECIFICATION
DESIGN HAND BOOK
PILOT RUN
PROCESS BULLETINS
STRUCTURAL DESIGN DATA
MANUFACTURING STANDARDS
PROCESS SPECIFICATION MANUAL

Fig. 3 — Orderly transmittal of experimental and production data for evaluation of new materials in design

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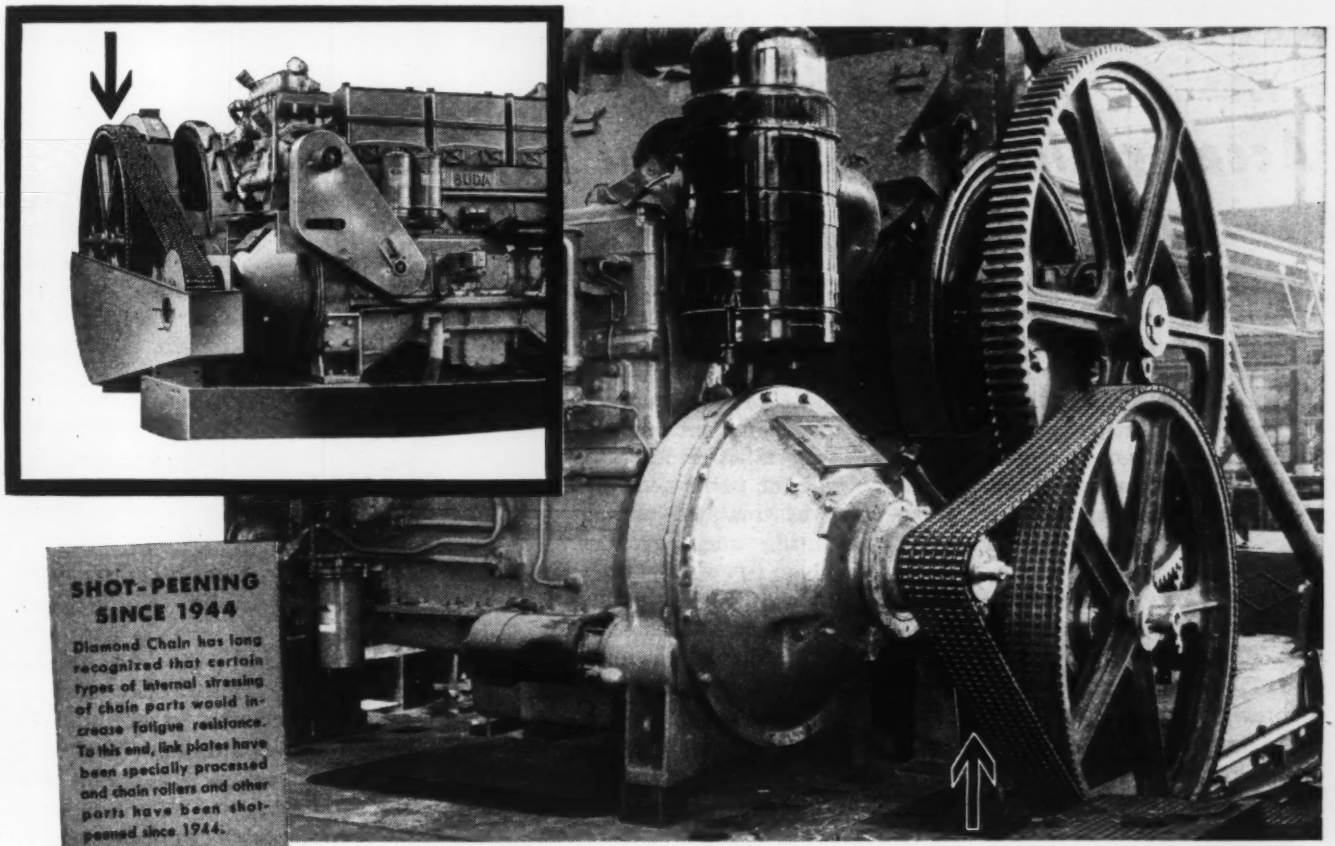
No Slip or Stretch . . . 98-99% Maintained Efficiency



SHOT-PEENING SINCE 1944

Diamond Chain has long recognized that certain types of internal stressing of chain parts would increase fatigue resistance. To this end, link plates have been specially processed and chain rollers and other parts have been shot-peened since 1944.

• Diamond Roller Chains cut maintenance and adjustment costs. The toughened side plates of great reserve strength take the shock loads and tension;—the hardened finished surfaces of the rollers, bushings and pins resist wear for longer useful life. At high, medium or slow speeds, operation is smooth and quiet with exact speed ratio maintained.

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ment work, not only to machine, forge, cast, form, or extrude the material, but also to adapt present equipment or design new equipment to do these operations.

On completion of the basic tests and cost considerations, it is advantageous to select a production part for a pilot line operation. In order to obtain the best comparative analysis it is desirable to utilize a part which has been produced from a similar material and on which all operations have been checked for labor and material costs.

When the selected part can be installed, a complete check can be made of any assembly or installation problems. Service inspection by the operator will furnish the final data necessary to complete the design criteria and fabricating limitations of the new material.

Transmittal of Data: During the testing for basic data it is of the utmost importance that a smooth flow of information, as it becomes available, be transmitted to the design and production departments. The flow of information shown in *Fig.* 3 has proved to be an orderly method covering preliminary experimental data and production information.

Development Organization: The introduction of a new material requires the services of the material producer, the final consumer, government agencies, and the manufacturers. Within each individual manufacturing organization a group of specialists consisting of metallurgists, chemists, and technicians, is necessary.

It is the responsibility of this group of specialists to develop and prove the practical application of the material for use in the final product. Through authoritative data to designers and manufacturing based on conclusive development, the majority of the guess work is removed from productionizing a new material.

From a paper entitled "Productionizing New Materials" presented at the Semiannual Meeting of the ASME in Los Angeles, Calif., June 1953.

Accelerating New Material Use

By J. Van Hamersveld

Supervisor of Producibility
Northrop Aircraft Inc.
Hawthorne, Calif.

UTILIZATION of titanium in current and future aircraft was studied by first arranging meetings with the producers of this material for a direct briefing on its properties, availability and cost. Trips were made to producers, parts manufacturers and other establishments to determine the state of the art of working with this material and to obtain first-hand information on production problems.

As a result of these meetings and observations of titanium fabrication problems being encountered, it was decided to form a "Titanium Usage Committee" to provide the following services:

1. Determine production usage of titanium
2. Investigate types of titanium alloys to be employed on airframes
3. Prevent production schedule tieups
4. Inform the manufacturing department of the company in advance of the types of titanium fabrication problems.

Committee Organization: This committee is composed of two groups: (1) the nucleus or permanent department members, and (2) the specialist or design group members. The permanent members consist of qualified personnel representing such groups as wing, fuselage, power plant, armanent, equipment, and structures who are particularly interested in the problems or applications under consideration at any given meeting. These specialists serve as regular members of the committee and have a voice equal to the other members.

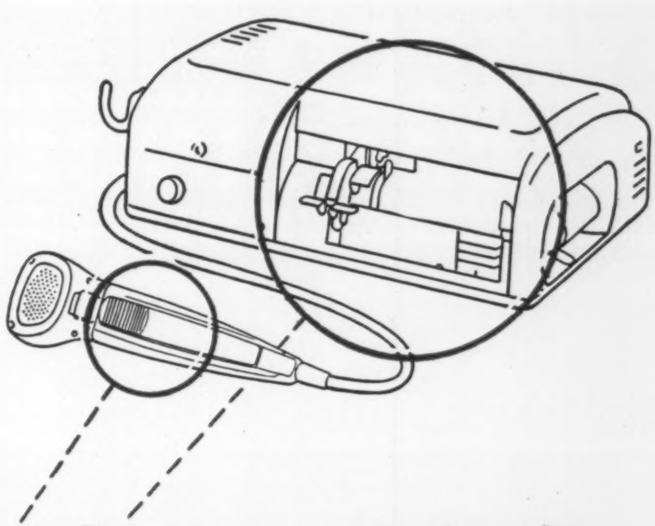
Operation of Committee: The main responsibilities of the committee are the following:

1. Review each proposed application of titanium and approve or disapprove its use with consideration given to weight, cost, fabrication, procurement, and logical substitution
2. Make recommendations to the various departments on action which it judges must be taken, and make suggestions concerning new methods or revised design.

Meetings are called whenever a design utilizing titanium is submitted for review. Generally, all such designs are screened by producibility engineering personnel prior to committee consideration. Obvious misapplications are discarded at this stage. After a decision as to titanium application is reached by the committee, a summary report is issued to all concerned, approving the particular design and indicating complete acceptance by the committee members.

Collection of Data: Shortly after the formation of the Titanium Usage Committee, the process engineering member was delegated the task of supplying decisive and detailed information regarding the properties of titanium. Such data were required in order to permit the committee to properly evaluate proposed design applications for an airplane which was under current development. Time was of the essence because of the close schedule. In view of the urgency of the situation, it was decided to accept this data as issued in memorandum form, pending the release of formal reports, process bulletins, etc.

Data Evaluation: Analytical Data were collected on short notice from all available sources and weighed against the source. Out of this collection of information—often conflicting, contradictory,



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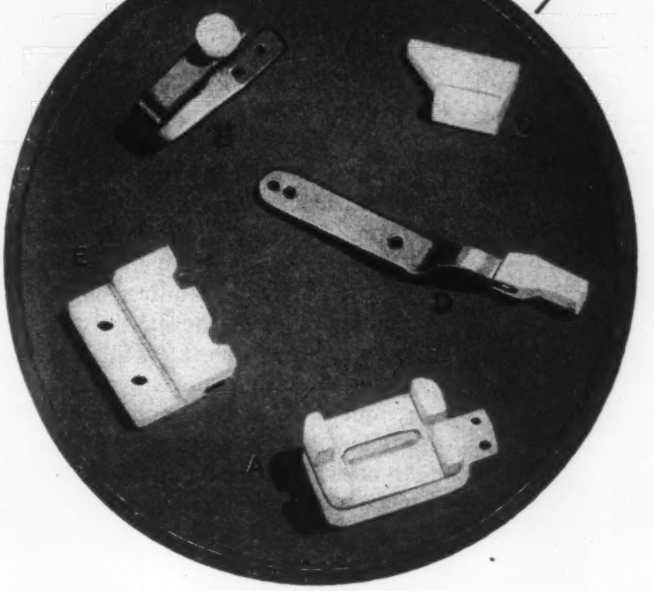

Parts molded of Du Pont nylon for the Dictaphone Corp., New York, N. Y., by Watertown Mfg. Co., Watertown, Conn., and Bridgeport Plastics & Rubber Co., Bridgeport, Conn.

Here's how key parts of Du Pont nylon have improved the performance of the Dictaphone Corporation's new Time-Master dictating machine. The *recorder coil bobbin* (a) is molded of Du Pont nylon because nylon is strong and tough in thin sections and has excellent insulating properties. Terminals can be riveted directly to it—eliminating an insulating part and cutting assembly time. The *microphone hook actuating lever* (b) required a material with good thermal stability. Molded nylon withstands high operating temperatures (up to 250°F.). These UL approved parts are tough, too—stand up to hard usage without cracking or breaking.

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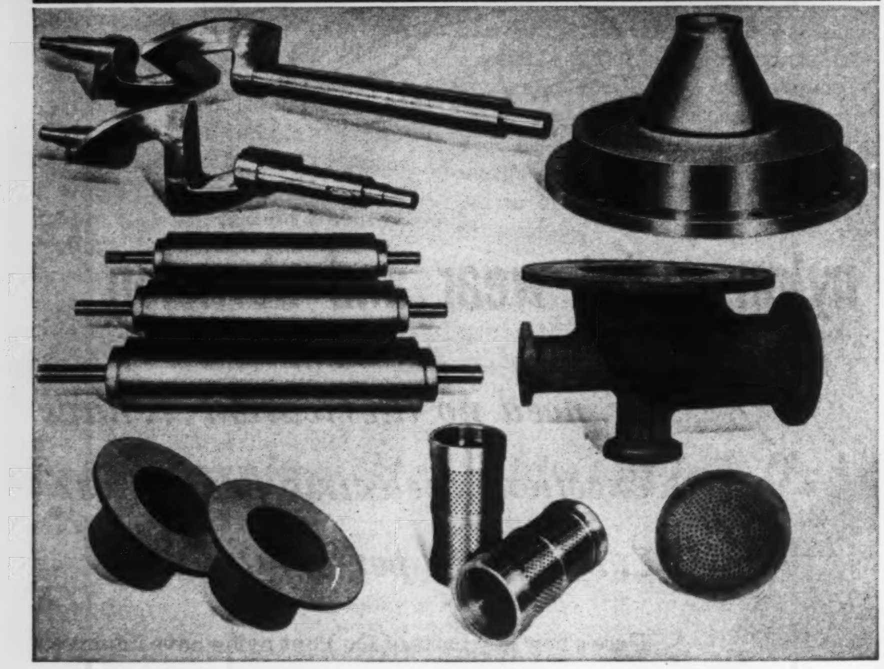

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anticipatory, optimistic or pessimistic—was chosen a set of assumptions upon which to base decisions. If any doubt existed as to the value of the information, a very conservative approach was made.

In many cases in which properties of the same titanium alloy showed a wide range of values, it was discovered upon investigation that tolerance differences existed in finished sheet stock. These variances had to be considered in design. Applications involving unknown quantities were rejected or held in abeyance pending availability of test data.

Design Practice: Necessary procedures which have been established for titanium substitution include notes on drawings for authorization to fabricate additional sets of standby substitute parts to insure meeting production schedules. Titanium and stainless steel counterparts are given different part dash numbers which are listed along with material thicknesses and substitution note in tabular block form. To insure adequate control, the actual use of substitute parts on each airplane requires engineering approval in each case.

In practice, due to rapid acceleration of design development programs, lack of time and funds precluded research on specific parts to verify and expand the fund of production data on which to base more complex designs. The lack of detailed information, such as weldability, formability, machinability, etc., did at times force rejection of applications which indicated that special requirements might develop during detail design such as stiffener beads, flanges or compound contoured sections that would be difficult to fabricate.

The lack of detail information always presents a challenge to the committee members, especially to the tooling and manufacturing representatives. But by being in on the embryonic design discussion of the application of a new material, these representatives know that they are an effective part of the team with every member willing to make the necessary compromise to obtain acceptance for the produc-

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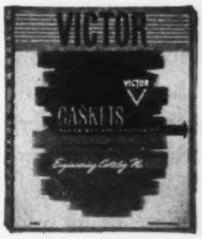

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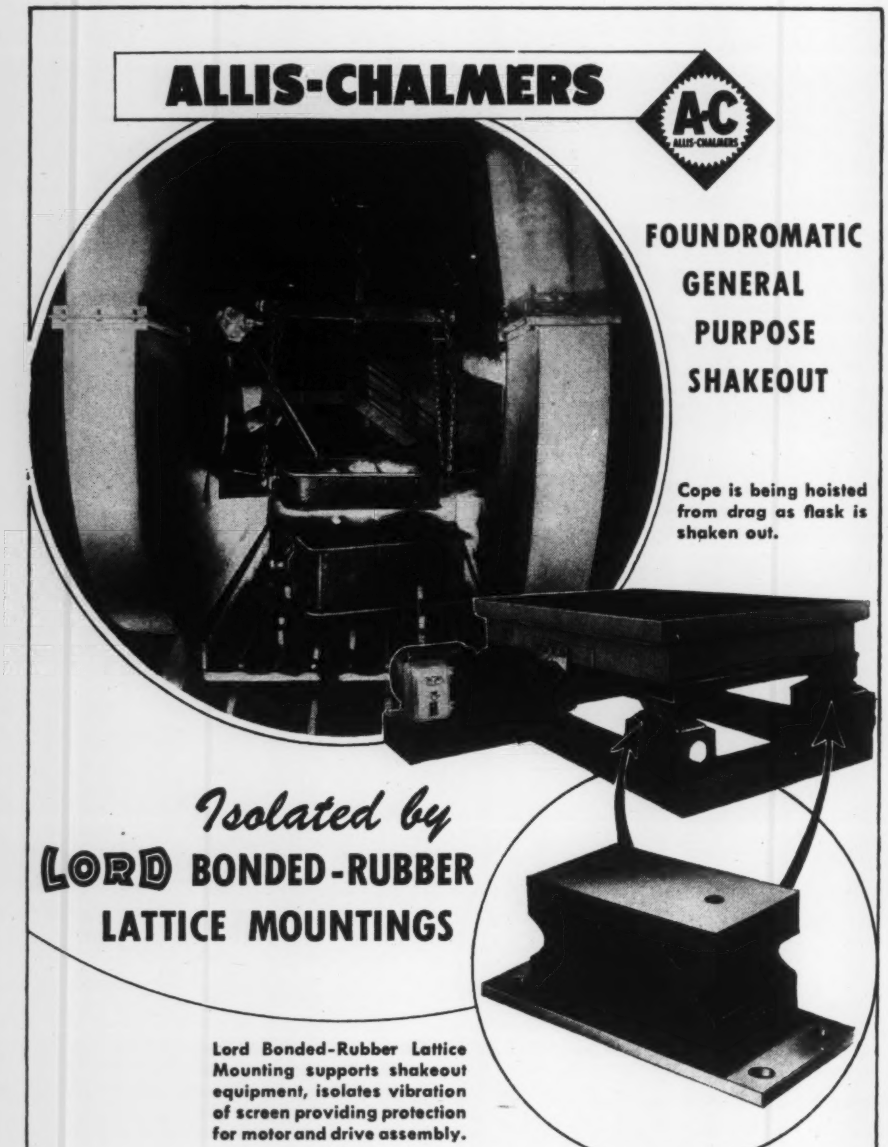

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tion of the items.

In some power plant applications involving double-curvature forming, it was decided that in the absence of detailed design information relative to titanium, design was to be based on the use of stainless steel, where applicable, and that the committee would later reconsider and recommend the use of titanium after all design requirements were established.

Fabrication: Applications of titanium which have been approved are those involving simple brake and roll forming, shearing and drilling operations for parts such as firewalls, rocket firing tubes, simple tension field beams, and flat and single curved panels in engine areas.

In all cases, approved titanium designs were initially applied to a limited block of airplanes. For purposes of shop planning, manufacturing, and tooling, flow times for titanium parts were considered to be same as for stainless steel.

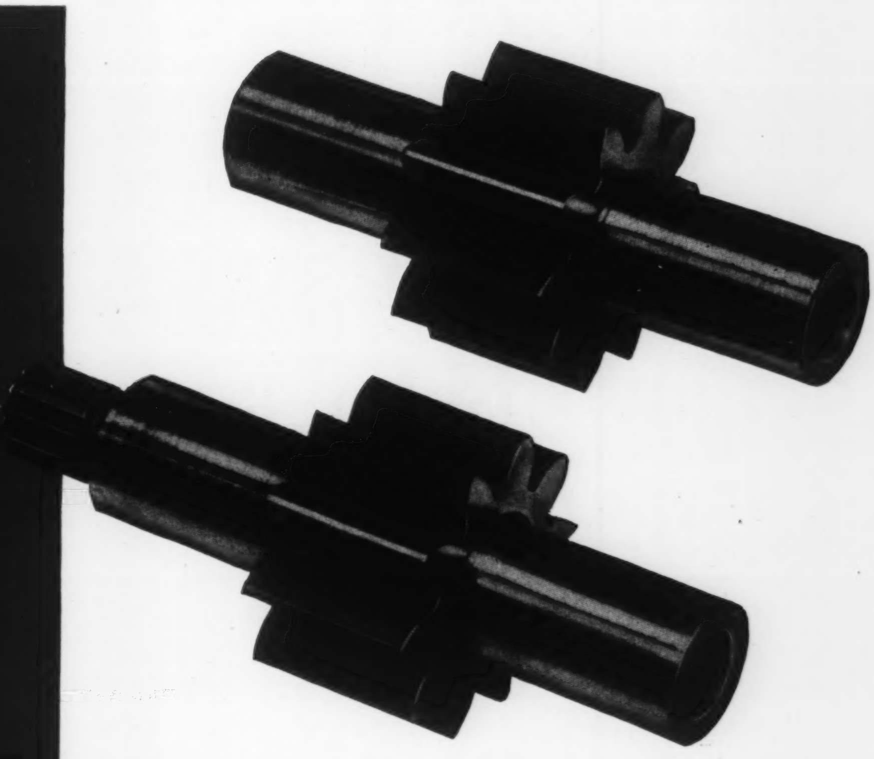
No chance was taken which would jeopardize production due to shortage of titanium or difficulties in fabrication. To insure certain continuity in the assembly line, adequate substitute materials were ordered at the same time as the titanium. Standby duplicate parts of these substitute materials were fabricated simultaneously with the titanium parts and were immediately available to the line.

Committee Results: The beneficial effects of the Titanium Usage Committee can be summarized as:

1. Quickly obtained the best available design information
2. Promoted plant-wide co-operation and co-ordination
3. Held down the cost of introduction of a new material into actual production
4. Indicated where to start research and development programs to secure more detailed design and fabrication data.

Any new types of materials could be "productionized" by expanding the scope of this usage committee.

From a comment on the paper "Productionizing New Materials" presented at the Semiannual Meet-



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ing of the ASME in Los Angeles, Calif., June 1953.

Applying Computers to Machine Control

By Mina Rees
Director
Mathematical Sciences Div.
Office of Naval Research
Navy Dept.
Washington, D. C.

THE FUTURE use of digital computers invites flights of fancy. For the immediate future we may look in two directions. One is toward the physical realization of a machine that will achieve greater reliability with greatly reduced size through the use of transistors, printed circuits, and crystal diodes; the other is a combination of new fast, large memories—the magnetic core is the most popular at the moment — with the fast arithmetic circuits that are already in being. Thus some of the scientific problems which have not yet been tackled or which have been only partially resolved because of the limitation of present machines, will be undertaken.

Among feedback-system engineers it is frequently held that almost any industrial process or operation could be made automatic if there were overwhelming economic arguments for doing so. Work steps have been taken toward establishing the automatic factory. The Signal Corps has a contract which is aimed at making possible the completely automatic manufacture of printed circuit electronic assemblies using conventional type components. The Ministry of Supply has placed contracts for the development of fully-automatic machinery for making special electronic tubes.

How likely is the total automatization of industry is a pleasant question to ask one's crystal ball. If it is safe to project recent trends, the self-regulation of industrial functions and some degree of automatization of industrial management will come in the not too distant future. In certain areas it is clear that we shall never dispense with human decisions, so that the threat of a productive system that runs itself completely appears to be unreal. However, in these days, one must admit, the automatic control-system engineer is being born. The introduction of automatic controls has already resulted in considerable conversion and retraining of unskilled labor, and in this direction we may look for further development. There is a danger of disruptive transients which may be expected if the coming of a new war should introduce substantial automatization of industry faster than the economy can adjust itself to it. In any case, we may look for social problems of readjustment and retraining with the introduction of largely automatic equipment.

Replacing Human Control: In spite of the elaborate instrumentation, it is a human being who meets emergencies in plants that are largely automatic. These plants are automatic only when the unexpected is not happening. In times of stress they fall back on human control and the whole design is dictated by this necessity. When it becomes possible to employ a digital information machine as an instrument of supervisory automatic control, the picture will change radically. Since such a machine can be instructed to perform any set of logical operations, however complicated, it can be programmed at the outset to react in emergencies precisely as would a well instructed human operator—and it can react at least a thousand times faster. Further, the machine can be given a set of criteria for appraising the relative success of its various acts, and can be enabled to alter its own program in the light of experience on the job. What is desired is a master controller which will continually analyze the end product, compute what changes must be made in the process conditions and signal instructions back to appropriate points.

Instructing the Machine: Digital machines will do exactly what you tell them to do. As Claude Shannon said, "A digital computer must be

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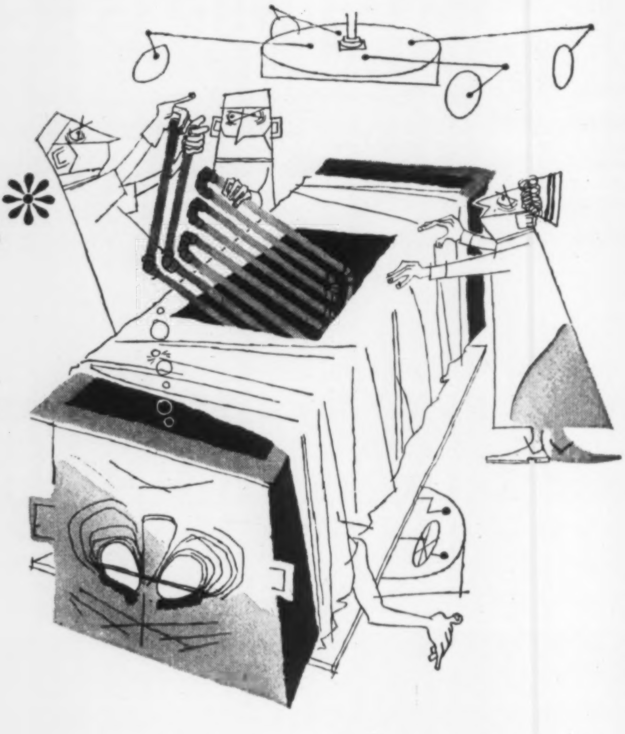

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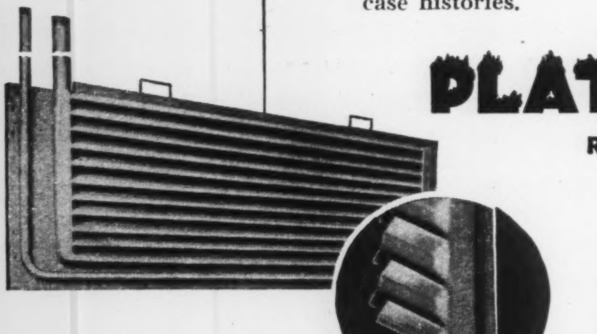

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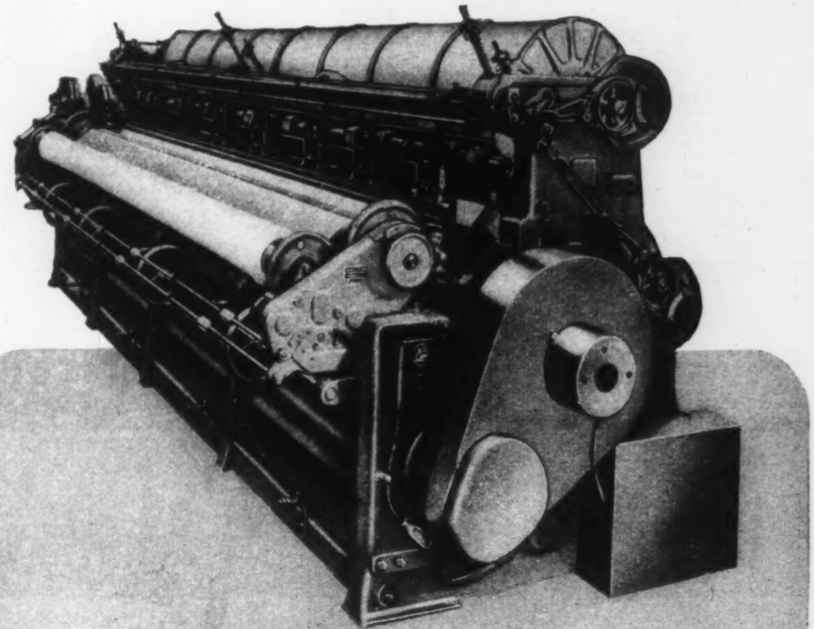
instructed in words of one microsyllable." Whether a machine is working on a scientific problem or operating as a control mechanism, or performing any of the manifold other functions that are contemplated for it, it must be given a precise and detailed breakdown of the problem which it can understand. Thus the distinctive first step which must be performed before these machines can be expected to enter into new fields of usefulness is a complete and careful analysis of the problem to be undertaken.

Automatic Machining: There are many ways in which we may look for the use of computers in industry. Already an experimental milling machine has been put into operation at the Massachusetts Institute of Technology. This is an automatically controlled high-precision profile cutter. The process of cutting a piece of metal to reproduce a prescribed shape with a high degree of accuracy has always been expensive and time consuming. It required the construction of a master template or cam or other guiding device. This had to be accurately followed, with an accurate link between the follower mechanism and the machine tool which was actually cutting the unshaped piece of metal. The MIT machine has replaced the cam and the follower mechanism by a digital computer. This computer has fed into it at small intervals before it starts its work, a set of numbers representing the changes in slope of the desired profile. These data are transformed in the computer to profile cutter commands, i.e., numbers representing the desired position and direction of motion of the cutting tool. The cutting tool is directed by a servomechanism which positions the tool so as to match the numbers coming out of the computer. As a result, a variety of shapes can readily be produced, in either large or small quantity, with very little cost of preparation, since only the changes in slope of the desired shape need be determined and punched on a special tape. It seems clear that the great flexibility and economy which this device provides will have significant repercussions in industrial practice.

Automatic Banking: Studies have been made of inventory control and accounting as they may be effected by the introduction of electronic computers. All these are in their early stages and are still concerned with a clear definition of the problem. In management problems of this sort, the main objective is to introduce quantitative methods to replace intuition. Studies are also going forward aimed at determining the degree of automatization which is realistic in large banks. The central difficulty here is also a legal one. There are redundant human operations in the handling of checks which are deposited at branch banks and later forwarded to a central sorting unit. But a check is in itself the legal document on which payment is to be made, so that it is not sufficient to convey within the bank and to other banks the information which resides in the check, but the check itself must be conveyed. An interesting proposal has been made by the International Telemeter Corp., which relies on attaching to the check at the time of the first branch operation a standard strip or edge bearing the coded information derived from the check. After this has been done, machine devices can operate upon this attached strip.

Machines that Learn: Some interesting work is going on in England under the leadership of Grey Walter and W. R. Ashby. The ordinary feedback of a machine makes it search for quantities that represent the difference between its results and the desired results. Walter and Ashby are seeking to build a machine in which the difference between the policies of the machine and the desired policies is also subjected to a feedback. Theirs is a machine which can learn and which can modify its behavior in terms of its own success or failure. Thus far the reported work of this British team is concerned with very simple machines, but we may look for substantial effort in the direc-

(*Continued on page* 334)



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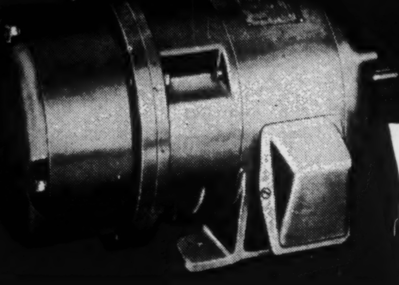

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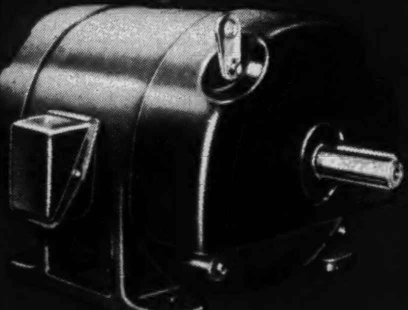

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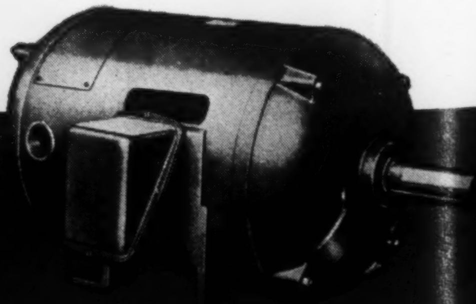

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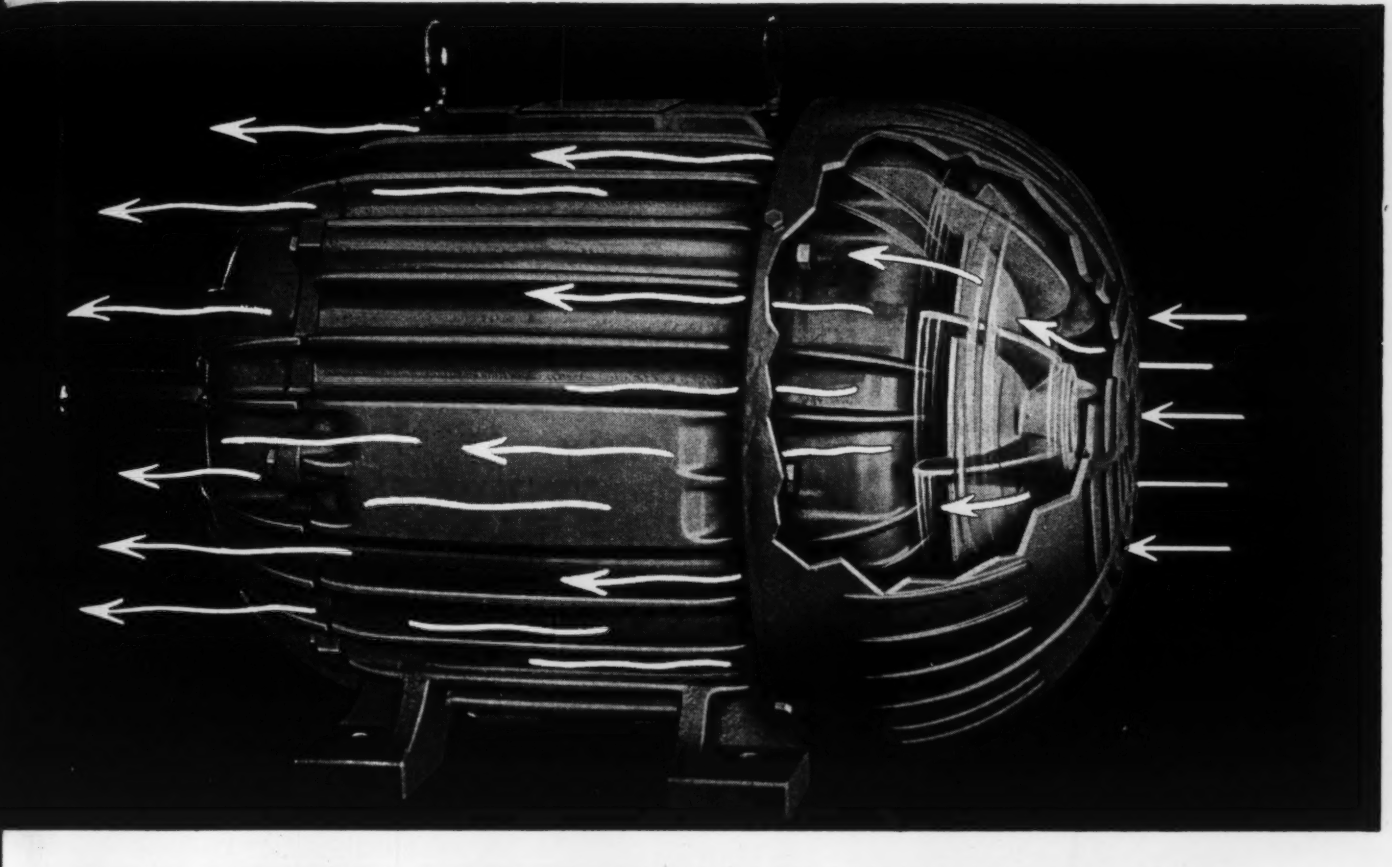

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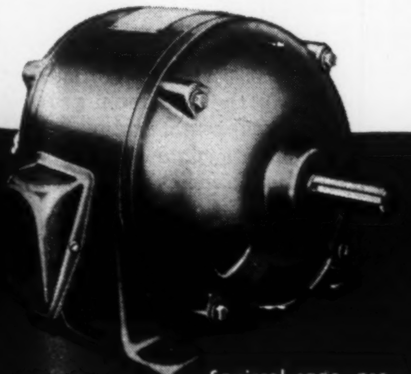

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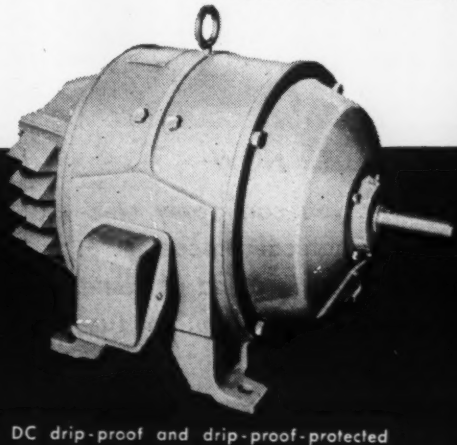
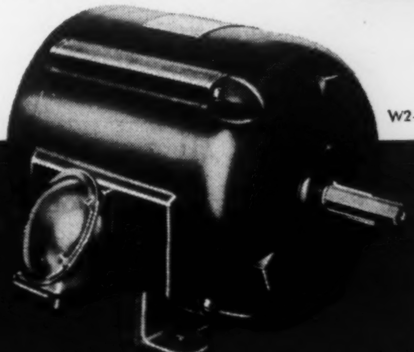
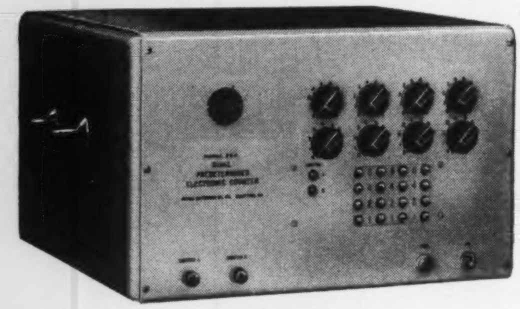


DC drip-proof and drip-proof-protected types. Form F, in ratings to 7½ hp. Form H, in 10 to 200 hp.



Squirrel-cage, totally-enclosed, non-ventilated Form BE. Available up to and including 3 hp at 1800 rpm, for applications requiring protection against dust, fumes, moisture.



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ANYTHING YOU CAN COUNT—YOU CAN CONTROL

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For quantity, volume, lineal measurement, shaft revolution, or weight at speeds as high as 60,000 units a minute, check these advantages of electronic machine control.

POSITIVE — Potter Instruments have the "complement" design which presets, counts, and controls *all in one circuit*. It uses fewer tubes and components, and it's fail-safe in operation.

AUTOMATIC — Reset and recycling are completely automatic. Count can be repeated indefinitely or changed at will.

MULTIPLE SEQUENCE — Control of high speed machinery is simplified. Two or more sequential predetermined counts provide precise steps for complex machine operation.

ACCURATE — Count one or count a million, the Potter Predetermined Counter counts exactly.

SIMPLE — Simple to operate and maintain because it is built to operate in factory installations.

GET ALL THE IMPORTANT FACTS NOW

Let Potter experts show you how easily you can apply electronic counter techniques to control mechanical processes. A complete line of detectors is available for every kind of count problem. We'll be glad to suggest a unit or a system. For further information, write Dept. 10M.

POTTER INSTRUMENT CO., INC.
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(*Continued from page* 331)

tion of machines that can learn by experience.

In all applications of digital computers, the computer must be fully instructed. The first step in this direction is a careful analysis of the problem. Any realistic approach to the introduction of computers in going business concerns must start with the status quo and proceed by modest steps into the future.

From an address entitled "The Future Use of Digital Computers" presented at the Eighteenth National Applied Mechanics Conference of the ASME in Minneapolis, Minn., June 1953.

Designing Large Forgings

By Chris W. Andrews
Douglas Aircraft Co. Inc.
Long Beach, Calif.

KEEN interest in the use of large forgings has been stimulated by demands for greater structural efficiency and by the potential size and production capacity of the government-sponsored heavy-press program. Attainment of greater structural efficiency through the use of well-assigned large components has been well established. Quest for superiority in air power brings constantly increasing demands for higher performance. The contribution to higher performance can be accomplished by the structural designer in the development of greater efficiency in structure by:

1. Selection and distribution of material giving the maximum possible strength-weight ratios.
2. Elimination of joints and their inherent inefficiencies and eccentricities.
3. Greater refinement of analysis.
4. Maximum utilization of testing to obtain efficiency in components which are difficult to analyze.
5. Design of multipurpose instead of monopurpose elements.
6. Proper consideration of the importance of external structure design to aerodynamic efficiency.
7. Consideration of the importance

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of rigidity in the basic structure to dynamic efficiency.

The greatest efficiency may result in the evolution of an aircraft having a single homogeneous structure. Idealistic as this philosophy may appear, an approach to this goal is being attempted by the gradual development of larger single structural components. Advances made in the production of materials and material forms such as extrusions, castings, plate, sheet, and forgings and the existence of supporting equipment and machinery for fabricating these materials have permitted an expansion of the designer's structural concepts. The utilization of large forgings in modern aircraft is a part of this concept.

Most designers will agree that a gain in structural efficiency and performance can result from the use of a larger component properly designed. Other factors, however, must also be considered. Decisions relative to the usage of large forgings must compromise all the factors in a manner which will produce the greatest net gain to the aircraft. The importance of one factor over another may be dependent upon the type of aircraft under design. An extremely high-performance military aircraft may require prime emphasis on strength and weight, while a commercial transport may require equal emphasis on cost and other types of aircraft may require high emphasis on producibility. Complete evaluation of the design problem and the use of good judgment are the primary requisites in the selection of components for large forging design. As forgings grow larger, several factors appear to warrant special considerations: (1) Strength, (2) weight, (3) cost, (4) availability, and (5) quality.

Strength: Since forgings are used, in general, for primary structural components, an awareness of the effect of forging size on strength characteristics is very important. In considering strength, the plan area of the forging is not particularly critical; however, the thickness and cross-sectional area are critical for as they increase, the material properties decrease in

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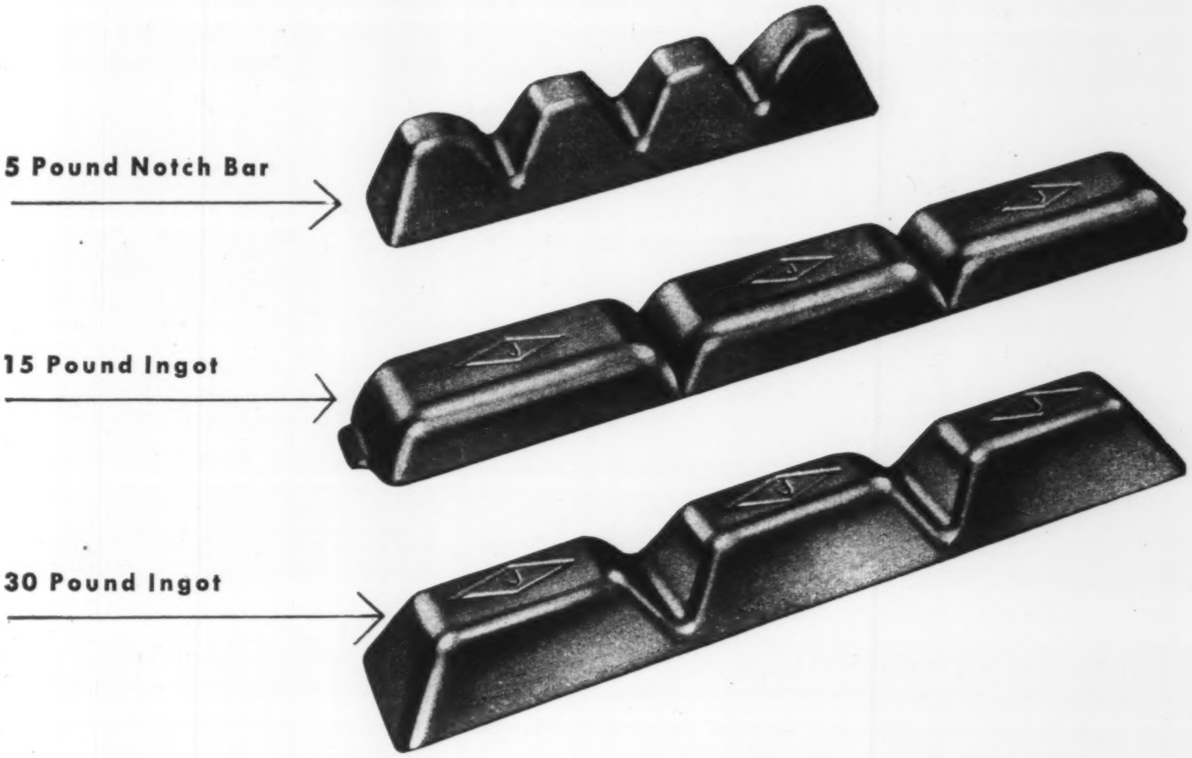

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ELECTRO MECHANICAL

Engineers

For research and development of electro-mechanical radar and computing equipment.

Significant advancements in the fields of airborne radar and fire control systems are requiring further applications of electro-mechanical techniques in the Hughes Radar Laboratory.

The company

Hughes Research and Development Laboratories, located in Southern California, form one of the nation's leading electronics organizations. The Laboratories are presently engaged in the development of advanced electronic systems and devices which are produced by the Hughes manufacturing divisions.

Areas of work

The work calls for devising reliable, maintainable, manufacturable designs for precision equipment developed in the Hughes Radar Laboratory. The equipment consists of mechanical, electronic and microwave devices and systems to be manufactured in quantity. The equipment designs require the use of such advanced techniques as subminiaturization, unitized "plug-in" construction, with emphasis on design for volume production. Knowledge of electronic components, materials, finishes and specifications is useful.

The future

Engineers experienced in the field of electro-mechanical design for production or those interested in entering this field will find outlets for their abilities and imagination in these activity areas. New electro-mechanical techniques are opening new applications for airborne electronic equipment. Hughes engineers will have the full benefit of working experience in these fundamental developments.

Assurance is required that the relocation of the applicant will not cause the disruption of an urgent military project.

Address resume to **Scientific and Engineering Staff**

Hughes

Research and Development Laboratories

Culver City, Los Angeles County, California

two important ways:

1. Material becomes less uniform and is lower in strength and ductility. This condition results from a reduction in working of the material especially toward the center of the billet.
2. Ductility of the material becomes more directional with a marked decrease in the transverse directions. Lowest ductility is encountered in the short transverse directions.

These conditions are of particular importance in aluminum alloys. In 75S material the ultimate longitudinal tensile strength of billets less than 16 square inches in area is 4000 psi greater than billets exceeding 36 square inches in area. In the same billets, elongation in the longitudinal direction varies from 9 per cent in the small billets to 4 per cent in the large billets. The differences in strength and ductility become even more pronounced as directionality is considered. A longitudinal element in a small billet develops an ultimate tensile strength of 75,000 psi while a short transverse element in a large billet develops only 64,000 psi.

Design Precautions

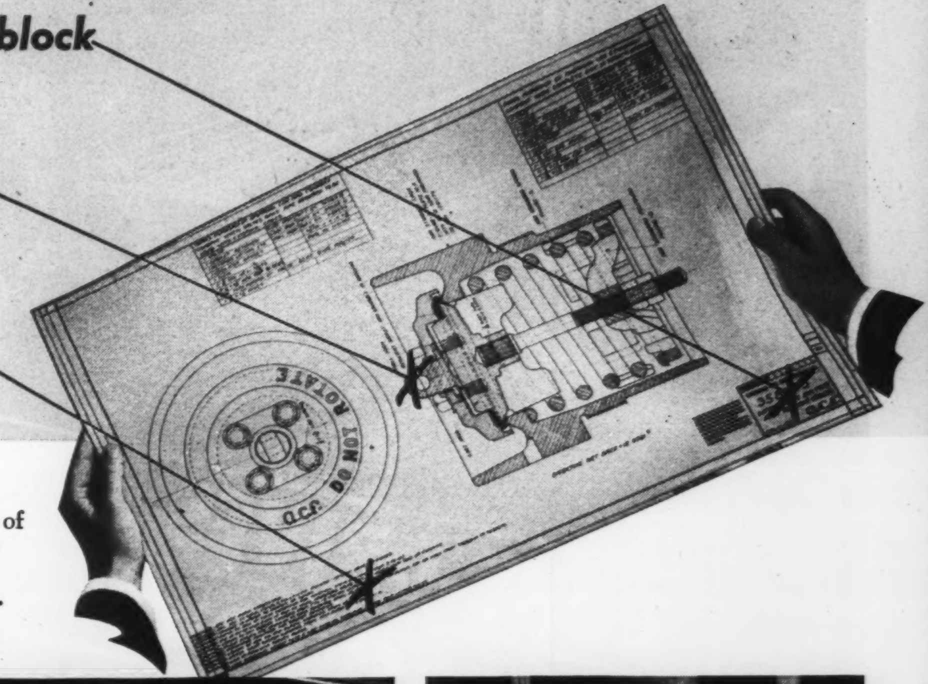
The reduction of strength and elongation with increases in thickness are a natural phenomenon with metals as is the increase in notch sensitivity with increases in ultimate strength. Neither has serious consequences as long as the designer is aware of the condition and provides for it in the design. Good design takes advantage of the desirable qualities of a material and avoids the pitfalls created by the undesirable qualities. With the growth in forging size, it is essential that the following precautions complement the normal design practices employed in smaller forging design:

1. Maintain the smallest possible cross-sectional area compatible with final part requirement.
2. Avoid excessive thickness.
3. Avoid loading in the short transverse direction.
4. Account for reductions in strength and elongation due to size effects.
5. Specify rough machining of forg-

All these changes made

without one line of retracing

- **substitute new title block here**
- **transfer design to cloth**
- **delete shop notes and lot numbers**



The American Car and Foundry Company, at its Milton, Pa., plant, has to modify hundreds of drawings like the one shown here to meet Army Transportation Corps requirements. Retracing would be much too slow . . . much too expensive. But how else can the job be done? *Kodagraph Autopositive Materials are the welcome answer!*

First—a positive photographic intermediate is made without a negative step by reproducing the original paper drawing on Kodagraph Autopositive Paper. *A fast room-light operation consisting of exposure in a standard print-making machine . . . and processing in standard photographic solutions.* The A.C.F. title block and shop notes are "scissored out" of this print . . . only the essential design remains.

Next . . . the Autopositive cutout of the design area is positioned under a Kodagraph Autopositive Film print, which is a re-usable master containing only the Army Transportation Corps title block. Then this composite is reproduced on a sheet of Kodagraph Autopositive Cloth—the same simple operation as was used previously for processing Kodagraph Autopositive Paper and Film.

Result: a sparkling, extra-durable reproduction comparable to an ink-on-cloth tracing. And the job done—not on the drafting board—but almost entirely in the print-making machine.

Additional time and dollars are saved by using Kodagraph Autopositive Materials to produce print-making masters from specification sheets and blueprints, and protect against the loss of valuable originals.

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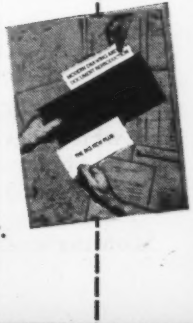
Write today for a free copy of "Modern Drawing and Document Reproduction." It gives complete details on the revolutionary line of Kodagraph Materials, which you, or your local blueprinter, can process conveniently, economically.



19

EASTMAN KODAK COMPANY,
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Gentlemen: Please send me a copy of your illustrated booklet giving the facts on Kodagraph Materials.

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ing prior to heat-treatment in order to obtain maximum material properties and corrosion resistance.

6. Carefully consider the grain direction for orientation with respect to loads.

Weight: The potential of weight reduction is one of the prime reasons for encouraging the use of large forgings. Substantial savings in weight can result from the elimination of joints and eccentricities and a more efficient disposition of material. Penalties imposed by splices in highly loaded members and the attachment of major fittings are well known. Any device which can minimize these penalties must be employed. Care must be exercised, however, to prevent weight penalties resulting from the use of the forging itself. The attainment of maximum efficiency in structure demands that a minimum amount of material be used and that this material work to the highest possible stress level. In beams, the web thickness should be no greater than required by the shear load. The caps should taper in area with the variation of bending moment to maintain high stress levels. The beam cap centroids must be as far removed from the neutral axis as possible to produce max-

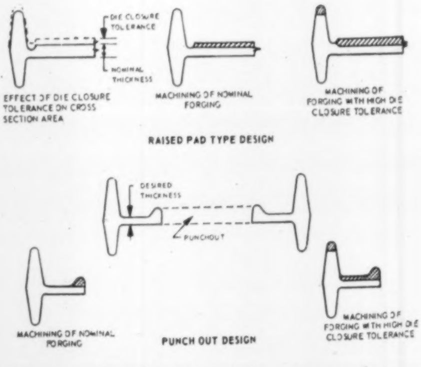
DESIRED THICKNESS
Y
MINIMUM FORGEABLE THICKNESS PLUS DIE CLOSURE TOLERANCE
CHANNEL TYPE DESIGN
RAISED PAD
DESIRED THICKNESS
DIE CLOSURE TOLERANCE
NOMINAL THICKNESS
EFFECT OF DIE CLOSURE TOLERANCE ON CROSS SECTION AREA
MACHINING OF NOMINAL FORGING
MACHINING OF FORGING WITH HIGH DIE CLOSURE TOLERANCE
RAISED PAD TYPE DESIGN
DESIRED THICKNESS
PUNCHOUT
MACHINING OF NOMINAL FORGING
PUNCH OUT DESIGN
MACHINING OF FORGING WITH HIGH DIE CLOSURE TOLERANCE

Fig. 1—Web shapes for large forgings which have been successfully used to obtain required thicknesses at low cost

Ten CONE-DRIVES® give compact power to steel mill crane

Morgan Engineering Company's 350-ton, 76-ft.-span ladle crane bridge features six individual 65-hp. motor drives that avoid line shaft designs.

Key to the success of this design incorporating parallel drives is the 12-in. center distance, 12/1 Cone-Drive gearset in each drive that cuts space requirements, resists shock loads and provides ample safety factor for smooth, rugged, long life operation.

Cone-Drive gearsets are also included in the drives for the 200-hp. main trolley hoists and auxiliary 20-ton and 60-ton hoists.

This is another example of the trend to Cone-Drive gearsets and standard speed reducers in steel mill equipment. Designers and users alike benefit from their long life and high capacity in less space at lower cost.

ALL TEETH IN CONTACT
45°

Standard double-enveloping Cone-Drive gearsets and reducers have greater contact per tooth, more teeth in contact, increased load capacity, greater shock load capacity, longer life, lighter weight—and lower overall cost.

Ask for "Cone-Drive Gears at Work in Industry" (Bulletin No. CD [illegible]) for your library.

CONE-DRIVE GEARS
Division Michigan Tool Company
DOUBLE ENVELOPING GEAR SETS & SPEED REDUCERS
7171 E. McNichols Road • Detroit 12, Michigan

imum section properties for minimum weight. These requirements have brought demands for thinner webs and smaller draft angles in die forgings. If suitable thickness and draft cannot be produced in the die-forging blank, then they must be machined into the finished part. The design must recognize this condition and provide for economical reduction of thickness by machining.

Several design configurations, illustrated in *Fig.* 1, have been used to obtain desired thickness at low cost. The channel type of design is highly recommended where it can be used. The "Y" dimension can be accurately held since the cavity is entirely within one die and the die closure tolerance is accumulated in the web which can be easily reduced in thickness by a simple slab-type cut. As a result, the weight of such parts can be very consistent. The raised-pad type of design can be used where an "I" section is desired. This configuration is satisfactory, if there is zero die closure tolerance. If large closure tolerances exist, this type of design may not prove advantageous and weight control with simple minimum machining may not be possible. The system of providing punchouts is also satisfactory providing die-closure tolerances can be minimized.

Cost: Experience has proved that savings in money, manpower, and elapsed time can be achieved by the substitution of well-designed single-forged units in lieu of complicated multipiece assemblies. The determination of a plus or minus sign in front of the dollar sign is dependent upon the designers ability to:

1. Select the proper application.
2. Select the proper material.
3. Use known design practices which minimize die cost.
4. Blend the forged blank and finished product designs to avoid complex machining.

Forgings are used generally where their qualities of strength, grain orientation, and material disposition are most useful. In view of the large tolerances associated

(*Continued on page* 344)

Continuous baking with trouble-free CONE-DRIVE® power

Petersen Oven Company's Ec-Tri-Flex 73" production bakery oven is an example of modern food processing equipment designed for maintenance-free, continuous operation.

A conveyor moves bakery products through the oven continuously on 21 stabilized transite trays. If the conveyor stops, food can be ruined. Shutdowns for conveyor drive repairs can ruin the best production schedule.

Petersen engineers insured against this danger by using a **standard** 3" center distance 40/1 Cone-Drive speed reducer in the conveyor drive system. And, this reducer has given trouble-free service in over 30 installations.

Standard Cone-Drive speed reducers and gearsets are providing similar 'service reports' throughout the food industry. As off-the-shelf replacement units, they can modernize your present equipment.

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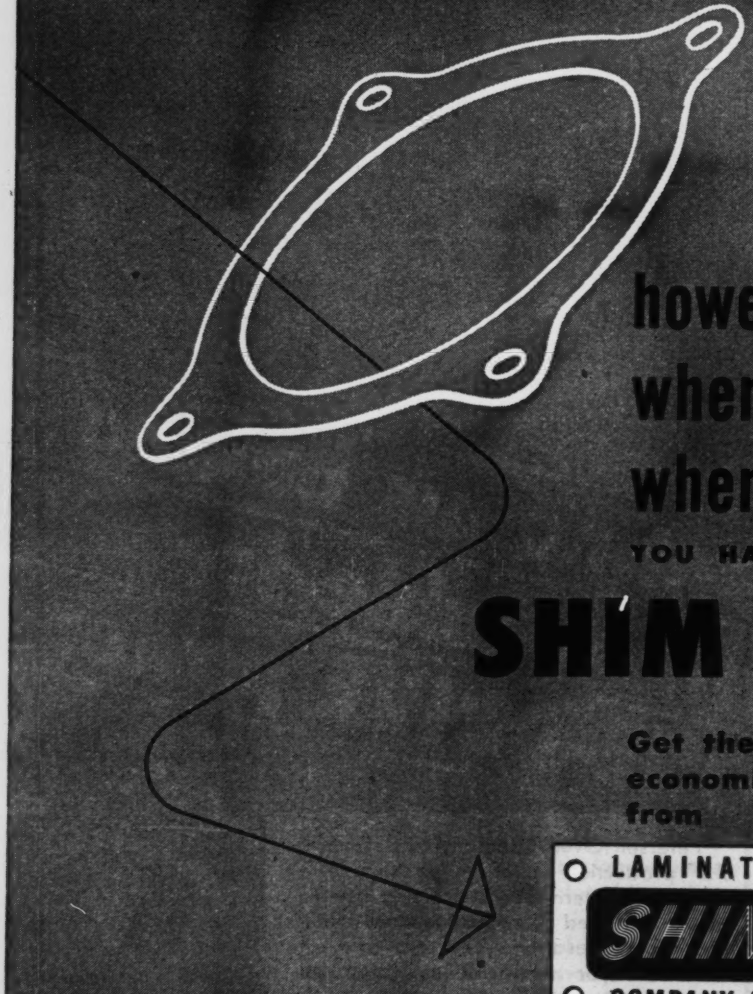

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Shim design is modern design. It saves **precious, extra, needed** hours of machining parts to needlessly close tolerances.

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So — when you face a shim situation, it will pay you to check with "Shim Headquarters." Don't just buy a **stamping** when you need a **shim.** Our engineering service can be important to you.

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Here's a quick picture of the shimming methods which are at the disposal of designer and production engineer. In actual use, many factors affect choice of proper type, for shim engineering has become a science unto itself. Be sure you check with us for an impartial recommendation. Remember that only The Laminated Shim Company offers you all 5 types of shims.

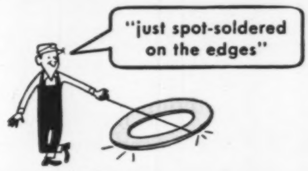
THE *LAMINUM* ® SHIM

"looks like solid metal!"

SIMPLY PEELS FOR ADJUSTMENT

The Laminum® Shim is made up of layers of .002 or .003 inch brass or steel, metallically bonded together over their entire surfaces. Peeling laminations with a penknife gives simple, accurate adjustment; no counting or miking is necessary. Shim is rigid, easy to handle, less compressible than solid metal. No grit can lodge between layers. Available in from 3 to 63 laminations.

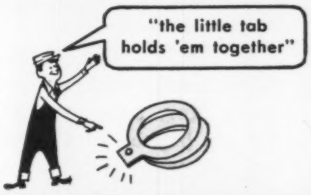
THE *LAMISOL* * SHIM


"just spot-soldered on the edges"

FOR QUICK, ASSEMBLY LINE USE

The laminations of the Lamisol Shim (in brass only) are joined by spot-soldering. This type of shim is just right for high speed, repetitive assemblies, regardless of the shim size involved. Spot-soldering makes a very firm "pack," but the laminations are quickly removed. Laminations within the same shim do not need to be all the same gauge, nor is the maximum number of layers limited.

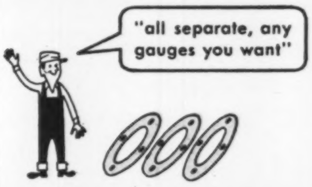
THE *LAMITAB* * SHIM


"the little tab holds 'em together"

FOR SUPER SPEED, THIN GAUGE SITUATIONS

The Lamitab Shim is a patented exclusive developed by us for the extremely fast moving production line. The little tab holds the shims together firmly, yet is easily removed. Different metals can be used in the same shim. The Lamitab Shim is unsurpassed. cost-wise and time-wise when properly engineered. Maximum number of laminations is 4. to a total thickness of .010 inch.

THE LOOSE LEAF SHIM


"all separate, any gauges you want"

FOR UNLIMITED FLEXIBILITY

The loose leaf shim is the simplest of all custom-stamped shims. It is completely flexible. There is no limit on number or gauge of each shim — and an occasional situation will require this "wide open" adjustment. In such cases, sets incorporating a variety of gauges are made up. Then, by removing one gauge and inserting another, a full scale of fine gauge adjustment is made possible.

PACKAGED SHIM STOCK

"swell for hand cutting simple shims"

READY FOR EASY USE, WITHOUT WASTE

Our Packaged Shim Stock is available for maintenance work from your Industrial Distributor. 6" x 100" roll feeds through package slots, *as it's used*. Available in 11 gauges, from .001 to .010", brass and steel. Heavier gauges to .032 are packed flat, two 6 x 25" sheets to an envelope. Laminated shim stock for maintenance use is also available in a variety of thicknesses and lamination arrangements.

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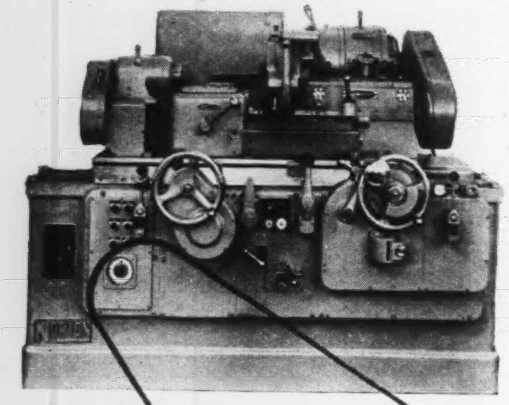
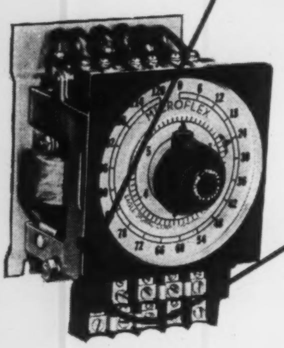
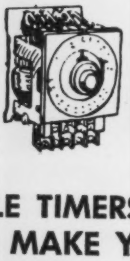


NORTON 6 x 18" TYPE CTU SEMI AUTOMATIC CYLINDRICAL GRINDING MACHINE

YOU CAN INCREASE PROFIT IN YOUR INDUSTRIAL APPLICATION



The new Norton Machine shown above, greatly increases profit in its' operation of cylindrical grinding. This machine incorporates an Eagle Microflex Timer for accurate, time control. Eagle manufactures a timer for your application or a complete control panel to automatically control your entire process. Increase your profit; send your problem to Eagle today.



EAGLE TIMERS WILL MAKE YOUR MACHINES AUTOMATIC

EAGLE SIGNAL
Industrial Timers
EAGLE SIGNAL CORPORATION MOLINE, ILL.

(*Continued from page* 341)

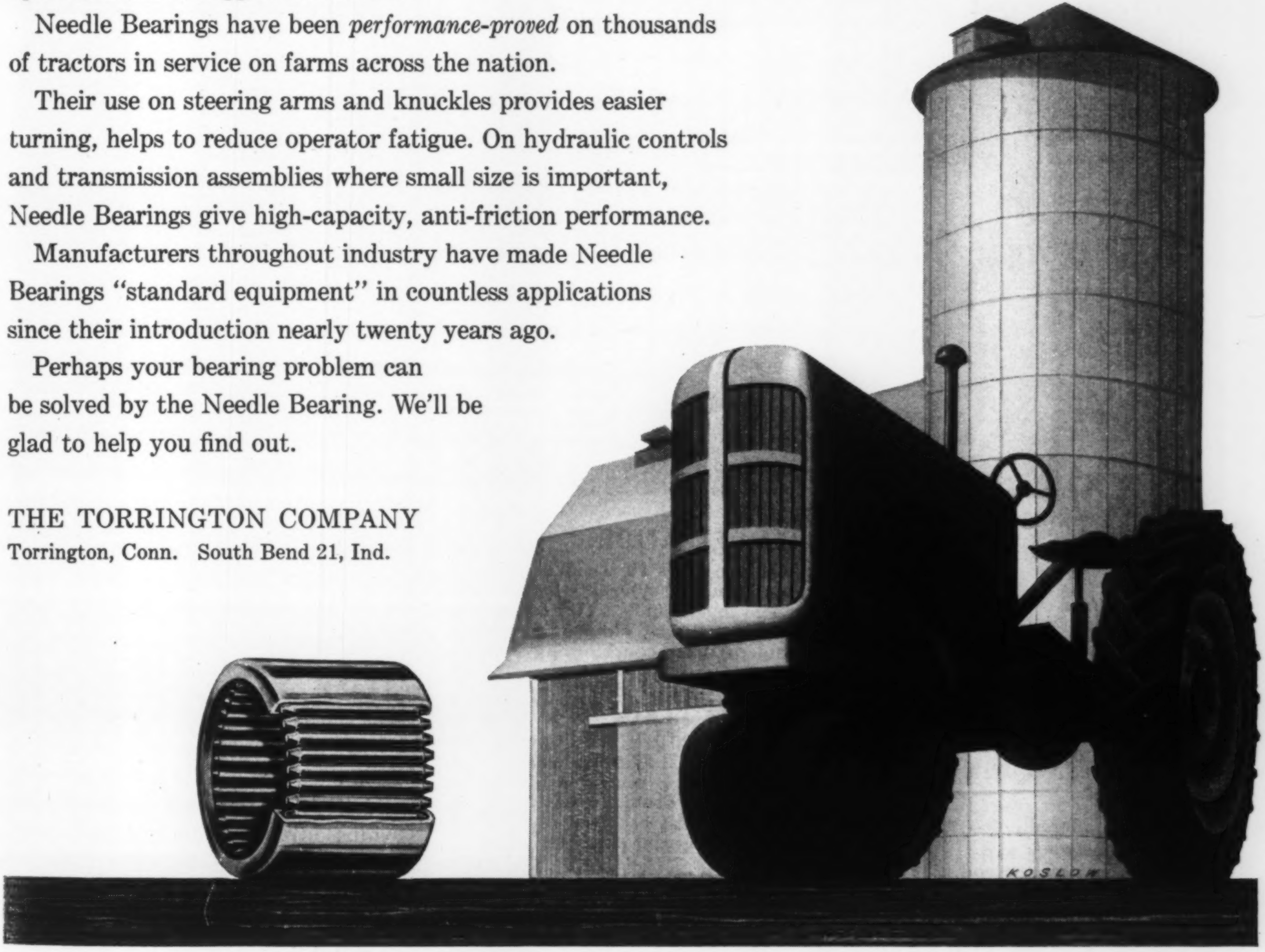
with forgings, it would be foolish to use forgings where closer tolerance extrusions could be used at no penalty in strength and a possible saving in cost. Typical applications for large forgings are wing spars, heavily loaded frames, ribs and bulkheads, floor beams, gear support structure, and major attach fittings. Most of these examples represent flat-webbed beam or truss-type of construction and lend themselves to reasonable forging production. Complex single or double-contoured elements in large sizes may be possible in the new heavy presses. As the design deviates from a flat plane, however, die machining becomes more difficult, side thrusts are induced, and in general costs rise severely.

Availability: The design of an aircraft, or any element of that aircraft, is the beginning of a cycle. The cycle ends when the last unit of that model ceases to exist. In the meantime, aircraft must be built within specified time limits and in specified quantities. Availablity of material, therefore, is of major concern.

Probability of die breakage has caused concern. As forgings grow larger, pressures will undoubtedly go higher and die-block sizes will increase. Higher pressures may lead to more frequent die failures. It is imperative, therefore, that the designer avoid poor design practices which lead to die checking or other types of die failure. Failures normally occur in the finish stage die. In this event, forgings from the blocker stage die may still be available. However, the use of blocker-die-type forgings may seriously hamper production schedules due to the increased machining required. A substantial quantity of milling equipment will be required to finish die forgings. It is doubtful that an additional demand could be placed on this equipment except for emergency purposes. Large forging proposals for the new presses probably should proceed on a somewhat conservative design basis until their capabilities of sustained production are proved. Large die blocks are long-time procurement items and die-sinking time is difficult to find. In those

Is long service life at low cost your problem?

here's how leading tractor manufacturers solve it with **NEEDLE BEARINGS**



Many makers of farm tractors specify Torrington Needle Bearings because of their relatively low cost and their long maintenance-free operation under rugged conditions.

Needle Bearings have been *performance-proved* on thousands of tractors in service on farms across the nation.

Their use on steering arms and knuckles provides easier turning, helps to reduce operator fatigue. On hydraulic controls and transmission assemblies where small size is important, Needle Bearings give high-capacity, anti-friction performance.

Manufacturers throughout industry have made Needle Bearings "standard equipment" in countless applications since their introduction nearly twenty years ago.

Perhaps your bearing problem can be solved by the Needle Bearing. We'll be glad to help you find out.

THE TORRINGTON COMPANY
Torrington, Conn. South Bend 21, Ind.

TORRINGTON *NEEDLE* BEARINGS

Needle • Spherical Roller • Tapered Roller • Straight Roller • Ball • Needle Rollers

Trade-marks of some of the manufacturers who use Needle Bearings

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JOHN DEERE QUALITY FARM EQUIPMENT
MASSEY M-H HARRIS
OLIVER
CATERPILLAR
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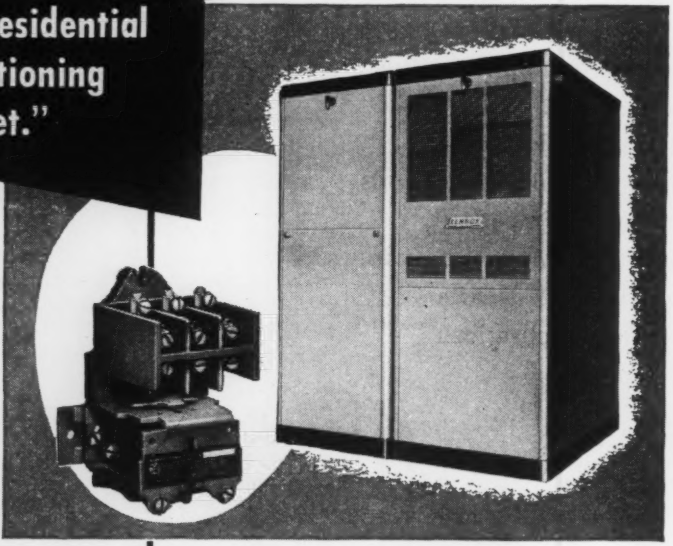
IH INTERNATIONAL HARVESTER
Ford
MM MINNEAPOLIS-MOLINE MODERN MACHINERY

Speaking of
FURNAS
CONTACTORS
Lennox Furnace says,
"Closest...to what
we consider ideal
for the residential
air conditioning
market."

KEEPING LENNOX HOME AIR CONDITIONING SYSTEMS working efficiently and quietly is the job of Furnas Electric magnetic contactors. Frank Osborn, air conditioning engineer at Lennox Furnace Company, gives these reasons why he selected Furnas Electric contactors:



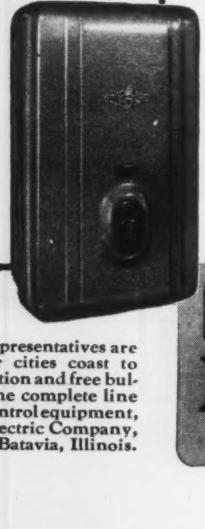
QUIET OPERATION:
Mr. Osborn likes Furnas Electric contactors because they are "relatively free of operating hum." He comments: "quietness . . . is of utmost importance in residential air conditioning applications."

EFFECTIVE PERFORMANCE:
Since residential air conditioning systems are subject to wide voltage fluctuations, Osborn points out that the Furnas Electric contactor has a big advantage with "its relatively low inrush and holding current characteristics."

LOW ORIGINAL COST:
The price of Furnas Electric contactors is hard to beat. Compared with other types, Mr. Osborn says this: "Furnas contactor is in a price and duty range more compatible with the residential appliance market."

These are important reasons why Furnas Electric contactors are especially suited for use on air conditioning systems. Proved in performance in a *wide range of applications,* Furnas Electric equipment has built a record that speaks with authority.

New Size 2½ Magnetic Contactor and Starter
Now being offered . . . another in-between size that saves you money and space. Available in reversing styles. Rated 20 hp at 208-550 v, 30 hp at 440-550 v ac polyphase; 5 hp at 110 v, 10 hp at 208-220 v ac single phase. Ask for bulletin on YG series.



Furnas Electric representatives are located in major cities coast to coast. For information and free bulletin describing the complete line of Furnas motor control equipment, write to Furnas Electric Company, 1045 McKee St., Batavia, Illinois.

FURNAS
ELECTRIC
Batavia, Illinois • Near Chicago

cases where an easy substitution can be made, or an existing element is redesigned, a more radical design approach possibly can be attempted without danger of disrupting schedules.

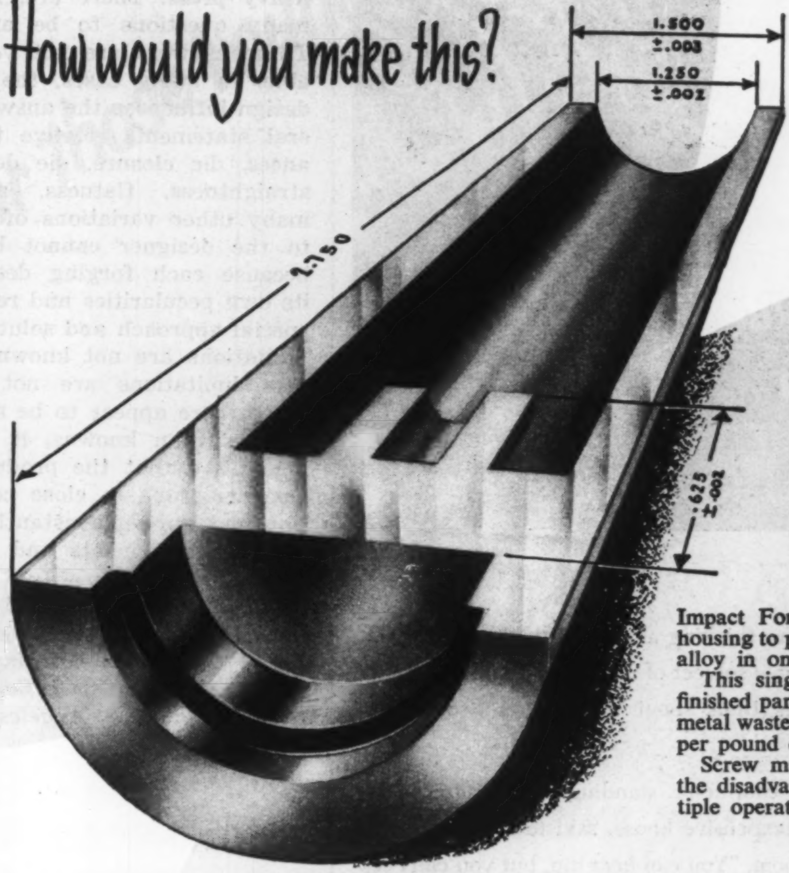
In considering availability, the designer must also determine whether sufficent milling capacity exists for transforming the forging to a finished usable part. Standard milling equipment will not be able to finish some of the large forgings contemplated. Large special equipment will be required and the availability of this equipment may influence the use of a large forging.

Quality: It is difficult to anticipate the effect of increased forging size on quality. The ability to produce larger ingots of good quality has not yet been established. If the material is sound in the ingot form and proper design is employed, the resulting forging should be sound. Most forging defects, such as laps, flow through, and cracked fillets, are visible on the surface and can be detected easily. Unhealed porosity, however, requires the use of sonic inspection devices for detection in most cases. As forgings grow larger it may be necessary to refine the quality-control procedures and expand the sonic inspection methods to assure high integrity. Warpage may not be classed as a quality item. However, it is an occurrence which is troublesome and can effect the quality of the end product. Residual stresses induced by the forging process are the main cause of warpage. Heat-treatment and machining procedures both have a tendency to relieve these stresses thus permitting the forging to twist or bend.

Conclusions: There is sufficient evidence from the existing presses to indicate that higher pressures can produce forgings with thinner webs and smaller draft angles. Grouping of equipment in the new press program provides greater assurance of availability. Capacity of the new presses implies an ability to produce larger forgings. Use of larger forgings from these presses provides the designer with an opportunity to obtain greater struc-

mr. design engineer...

How would you make this?



PRODUCED

34% cheaper...

7 times faster

Impact Forging reduced cost by forging this housing to print from a heat treatable aluminum alloy in one operation.

This single forging operation has produced finished parts many times faster, with negligible metal waste and increased yield of finished parts per pound of aluminum.

Screw machine production, by contrast, has the disadvantages of high cost bar stock, multiple operations and high metal waste.

IMPACT FORGING

—from HIGH STRENGTH ALUMINUM ALLOYS

Impact forging with high strength aluminum alloys is a new production technique perfected by Hunter Douglas. This new process produces parts with excellent tolerances, surface finish, and superior physical properties. In many cases production machining can be eliminated entirely; in every case machining is held to an absolute minimum. High strength parts of such alloys as 14ST6 ready for final assembly have been delivered at prices less than the cost of the bar stock alone when using ordinary methods.

Millions of impact forgings produced to date at low unit cost has proven the adaptability of impact forging to mass production requirements.

If you are now designing or producing a part requiring the properties of a forging, walls of zero draft, and close dimensional tolerances, let the Hunter Douglas engineering staff show you how you may reduce unit cost with aluminum impact forgings. Your blueprints, specifications, or sample parts will receive prompt analysis.

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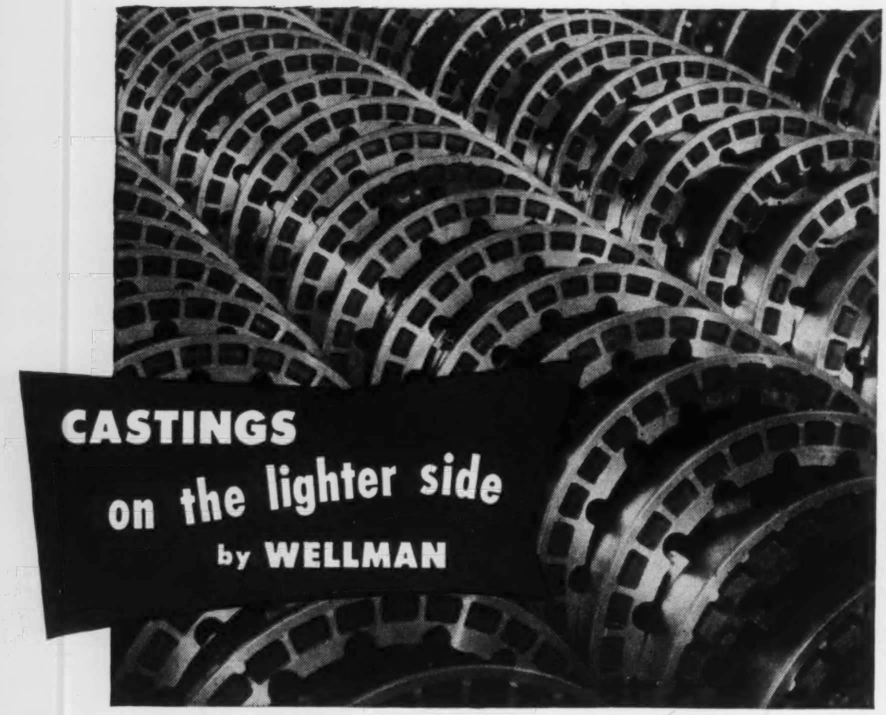

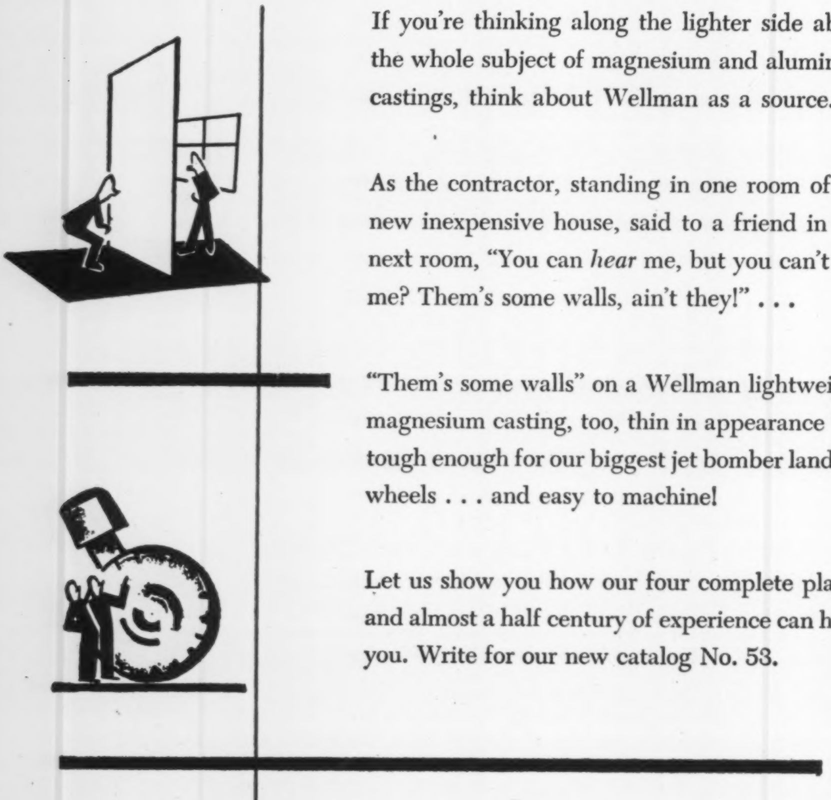

If you're thinking along the lighter side about the whole subject of magnesium and aluminum castings, think about Wellman as a source.

As the contractor, standing in one room of his new inexpensive house, said to a friend in the next room, "You can *hear* me, but you can't *see* me? Them's some walls, ain't they!" . . .

"Them's some walls" on a Wellman lightweight magnesium casting, too, thin in appearance but tough enough for our biggest jet bomber landing wheels . . . and easy to machine!

Let us show you how our four complete plants and almost a half century of experience can help you. Write for our new catalog No. 53.

Well-Cast MAGNESIUM AND ALUMINUM CASTINGS
Well-Made WOOD AND METAL PATTERNS

THE WELLMAN BRONZE & ALUMINUM CO.
Dept. 10, 12800 Shaker Boulevard Cleveland 20, Ohio

tural efficiency. This much is known about the large forging and heavy press. There are, however, many questions to be answered. These answers are not yet available. In many cases, the specific design influences the answer. General statements relative to tolerances, die closure, die deflection, straightness, flatness, and the many other variations of interest to the designer cannot be made because each forging design has its own pecularities and requires a special approach and solution. Size limitations are not known. Thickness limitations are not known. Since there appear to be more unknowns than knowns, it becomes imperative that the producer and designer work in close co-ordination and remain constantly aware of the requirements and capabilities.

From a paper entitled "Design Considerations Associated with Large Aluminum Forgings" presented at the ASME Semiannual Meeting in Los Angeles, Calif., July, 1953.

Creative Approach to Design

By L. W. Guth
Appliance Park
General Electric Co.
Louisville, Ky.

IS CREATIVE ability born in a man, or can he consciously and deliberately develop this ability? Perhaps the answer is that a combination of both shapes creative ability.

Substantiating the theory that man can acquire and develop creative ability, it is believed that creative engineering is in a part a combination of the following:

1. Active and inquisitive mind
2. Inner drive that is satisfied only by a job well done
3. Broad background of fundamental knowlege
4. Creative approach to any problem.

The first two requisites are characteristics inherent in the individual; the last two can be stimulated and developed. The pri-

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UNLIMITED SPEED RANGE. Only the Graham gives unlimited speed range from any desired maximum speed to zero, plus reverse if wanted, without stopping the motor.

BUILT-IN GEARBOXES. The Graham may be had with built-in reduction or step-up gearboxes — single reduction or double reduction spur or single reduction worm, thus saving the cost and complication of separate gear units.

UNMATCHED FOR ACCURACY. The Graham is unmatched for accuracy of speed setting and resetting and speed holding. The Graham may be held at the same setting for *continuous* operation — 24 hours a day for months or years, without alteration in speed, or its speed may be changed continuously on jobs requiring cyclic speed change. On the tough jobs requiring the ultimate in accuracy the Graham gets the bid.

NO PERISHABLE PARTS. The Graham has no perishable parts such as belts or tubes requiring periodic replacement. It is an all-metal, self-lubricated unit, built like the highest type speed reducer.

A PERFORMANCE RECORD. The Graham has a performance record of over fifteen years' satisfactory use as standard equipment by leading makers of machines (OEM buyers) such as conveyors, feeders, white printers, pumps, welding positioners, machine tool feeds, testing machines, integrators, printing machines, etc., etc.

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Such hose strength stems from a combination of special compar tube and modern synthetic yarns. Oilproof and non-aging, compar retains its initial high strength. Fortified with high tensile synthetic fibre braid, it needs no wire for medium-high pressure service.

This construction also provides five other outstanding features for *more hose value per dollar.*

1. *High Pull Strength*—as much as 3500 lbs for ½" hose—and couplings won't pull out even at this tension.
2. *Long Impulse Life*—virtually unlimited fatigue resistance to shock loads and impulse. Hose lasts longer.
3. *High Impact Strength*—hose returns to original cross section after crushing load.
4. *Full Flow at Fittings*—Less than 5% reduction in cross section at crimp.
5. *No Gumming or Clogging*—compar hose lines inert to all hydraulic oils.

For more information, write for Data Sheet MH-1.

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Made from uniform "Fluoroflex*-T" tubing—stress relieved before machining for dimensional stability of rings. These anti-extrusion rings withstand elevated temperatures. Self lubricating, they eliminate abrasion on "O" rings, reduce friction of the assembly. Chemically inert and non-fraying, they cause no malfunctioning of other hydraulic system components. Write for data sheet FR-1. **Resistoflex trademark*

RESISTOFLEX CORPORATION
Belleville 9, New Jersey

SPECIALLY ENGINEERED FLEXIBLE RESISTANT PRODUCTS FOR INDUSTRY

mary concern is with the fourth quality—a creative approach to design problems. But before taking this up, let's consider how problems are obtained.

Attention is generally concentrated on problems presented by management. To be most effective, a creative engineer must learn to sense a need rather than to have someone else do this for him. A true invention is made when an individual not only creates the form of the device but is also the one who recognizes the need for such a device.

To develop to positions of engineering leadership an engineer must learn to discover and develop new devices and concepts beyond the expressed needs of industry. A feeling of constructive discontent must also be nurtured. Develop the habit of asking yourself: What other ways can we do this? How can we improve this? Why don't we have a device to do this? New methods, new devices, new improvements will not be found—unless you look for them.

A willingness to contribute, accompanied by a mind prepared to explore new avenues, is essential to creative thinking. If an engineer's efficiency in thinking of new practical solutions is low, it is necessary that he be most prolific of ideas in order to produce a number of good inventions. The same applies to recognizing new problems.

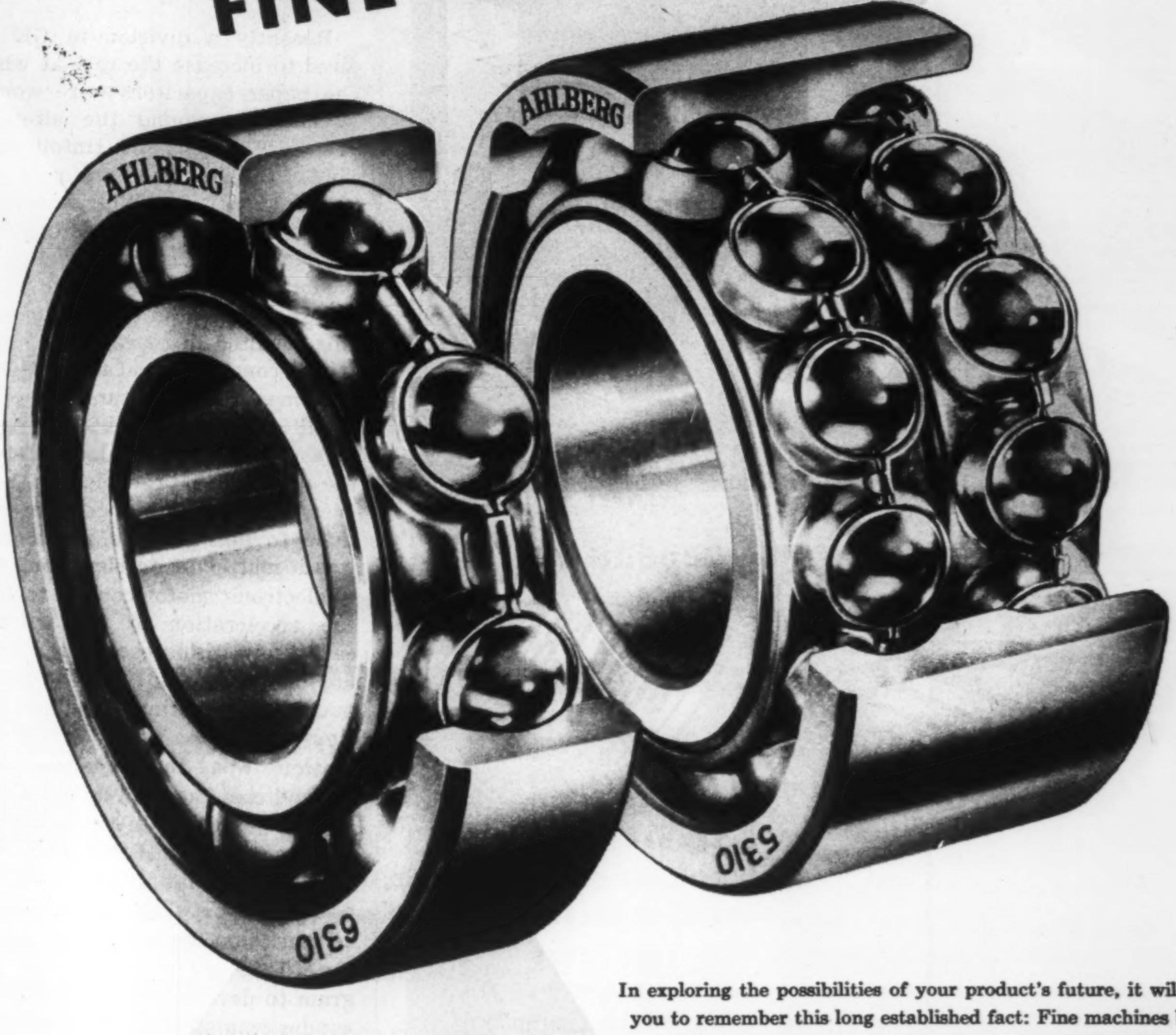
The approach to almost any design problem may be broken down into four basic phases:

1. Definition of problem
2. Search for method
3. Evaluation and selection of method
4. Solution

These constitute only the idea stage of the solution. If one is to produce consistently usable and worth-while solutions to problems, he must employ a creative approach.

Definition of Problem: When the design engineer tackles a new project, he gives particular attention to specifications—the first and highly important phase of solving a design problem. Specifications

Fine machines begin with FINE BEARINGS



In exploring the possibilities of your product's future, it will pay you to remember this long established fact: Fine machines begin with fine bearings—and fine bearings mean Ahlberg Bearings.

For over 45 years design engineers have found that Ahlberg Bearings offer greater opportunities for improving design, stretching equipment life, reducing maintenance and operating costs.

Ahlberg Ball Bearings are available in both self-contained and mounted units—in all conventional sizes. Write for complete data or engineering consultation on a no-obligation basis. Ahlberg Bearing Company, 3025 W. 47th Street, Chicago 32, Illinois.

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5 Teflon flexes, has good tensile strength, won't crack under vibration and has high impact strength.

6 Teflon prevents a carbonized conduction path that other materials permit.

*DuPont Trade-mark for tetrafluoroethylene resin

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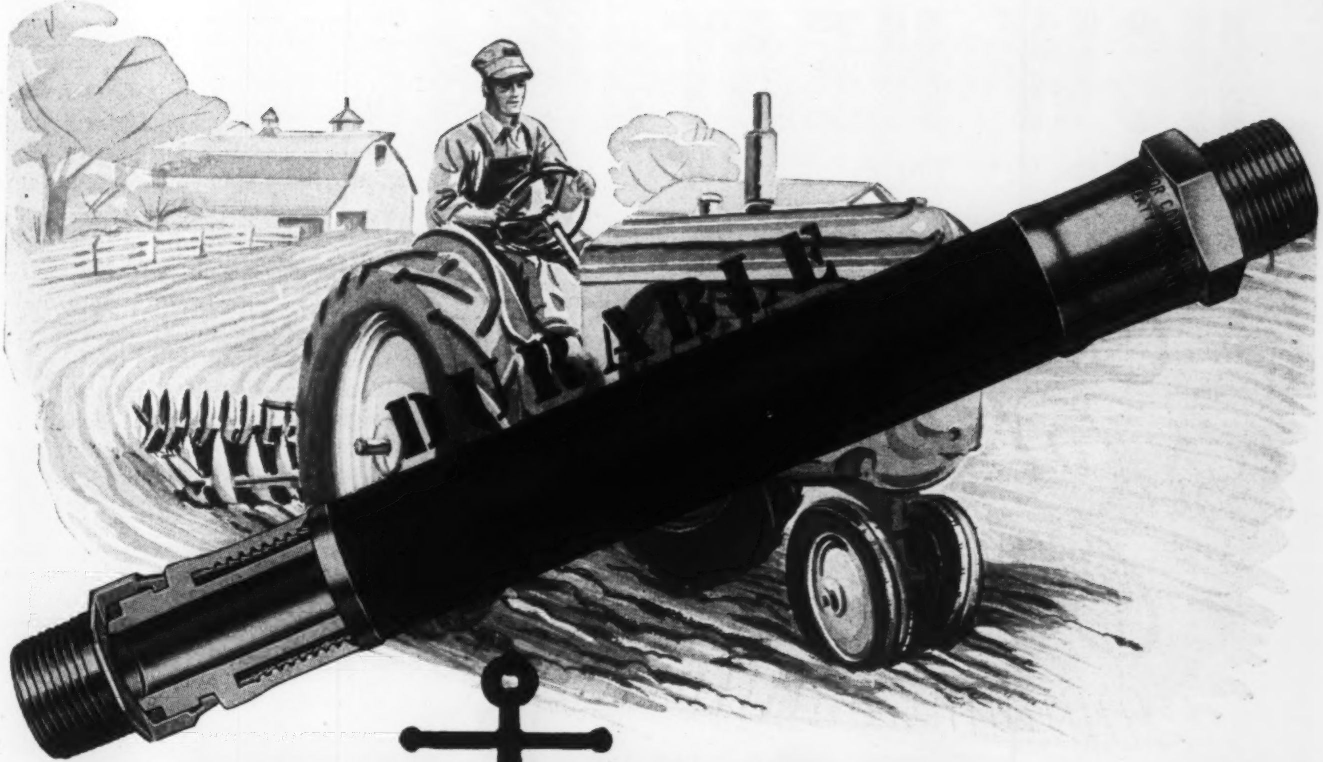
refer to the actual definition of the problem wherein many more factors than rating, weight, size, and other quantities are considered. The engineer must endeavor to investigate the fundamental problem involved.

Accelerating Production

Recently a division in GE desired to increase the rate at which the paper capacitors were wound. A machine wound the alternate layers of paper and tinfoil on a bobbin to make the basic part of a paper capacitor. When considering how these capacitors could be produced at a higher rate, the immediate solution seemed to be to increase the speed of rotation, but this resulted in tearing the paper. It was concluded that the difficulty was caused by moisture and other conditions that weakened the paper in such a way it could not stand the high speed. Close study, however, disclosed that speed had very little to do with the problem—it was a matter of acceleration. Use of electronic motor control to limit the acceleration of the machine easily solved this part of the problem. But still no increase in capacitor production resulted. A time-and-motion study of the operation was then made. This showed that most of the time consumed was spent in threading the machine and in feeding in two little tabs that make electrical connection between the plates and terminals on the completed capacitor. Thus, months after the program to develop a faster capacitor winder was started, the real problem was discovered. Perhaps the final approach seems obvious now, but all too often the obvious way becomes apparent only after costly false starts.

Liquid-filled capacitor leak testing reveals how more basic problems are often present. For example, if the container can be made leakproof, there is no need for leak testing. Even more basic would be a capacitor with the desired characteristics that does not use a fluid and hence has nothing to leak.

After a complete definition of



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ONE-WIRE BRAID HOSE ASSEMBLIES

for medium-and low-pressure service

Factory-assembled to your specifications—you get just what you need.

Long, uniform, positive grip assured by internally-threaded coupling shell.

Eliminates leaks and blow-offs in medium- and low-pressure service.

Sizes and types for every application — available with solid male or union male ends.

"O" ring seals prevent leakage between swivel ends and the coupling body.

Use of swivel male ends eliminates need for adapter unions, reduces the number of joints, and lets hose assume normal position when pressure is applied to the line.

Exclusive Anchor Max-Flo coupling gives you the equivalent of unrestricted flow through the couplings.

**NEW!
REVOLUTIONARY
ANCHOR FLANCO
SPLIT-FLANGE CLAMP**

Positive leakproof connection *without* threaded joints. Bolt centers are located to distribute the forces evenly and prevent tilting of the clamp halves. Easy to assemble with small automotive-type wrench.

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Yes, I'm interested in
☐ Anchor one-wire braid hose assemblies
☐ New Anchor Flanco Split-flange clamp-type coupling
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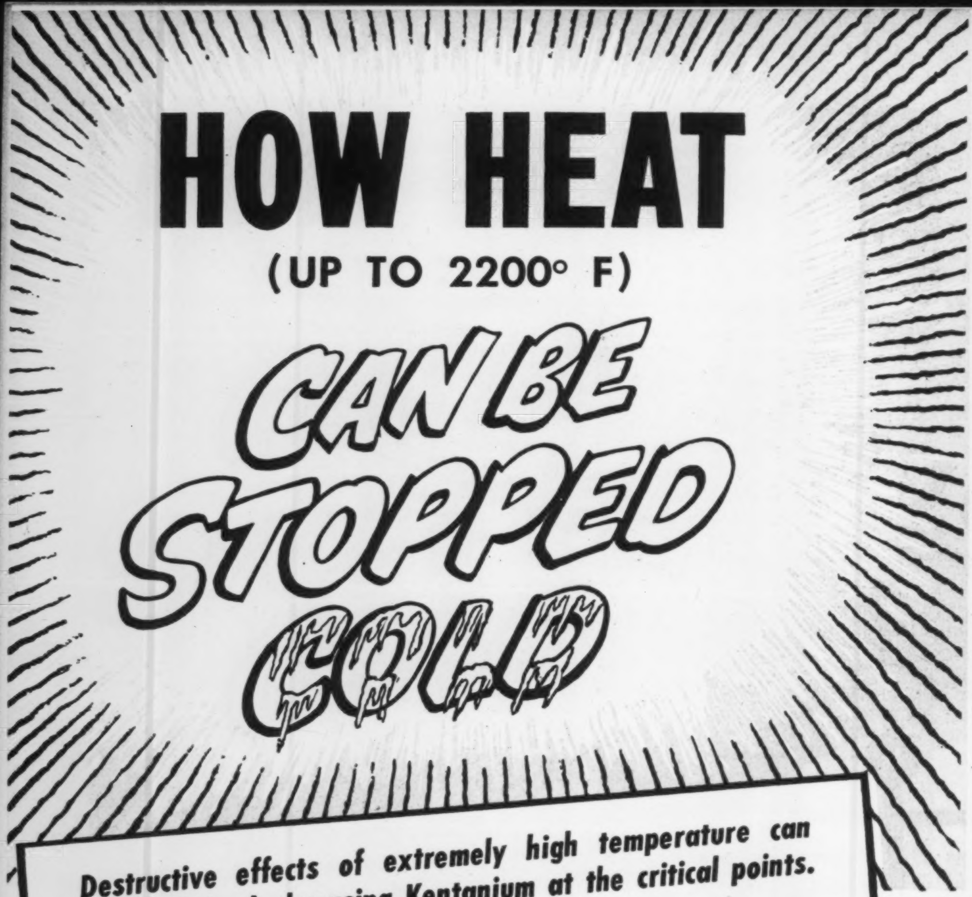


Destructive effects of extremely high temperature can be minimized—by using Kentanium at the critical points.

WHAT is Kentanium?	Chiefly titanium carbide (and small percentages of other refractory metal carbides), with nickel "binder". Uses neither tungsten nor cobalt. Hardness: Up to 93 RA. Weight: ⅔ that of steel.
WHAT can it do?	Resist thermal shock, withstand oxidation and abrasion, retain great strength at high temperatures (1800°F and above).
WHERE is it in use?	Successful applications include: Valves, valve seats, reduction crucibles, anvils for spot welding, hot extrusion die inserts, bushings, thermocouple protection tubes, flame tubes, furnace tong tips, balls for hot hardness testing, nozzle vanes and blades for jet engines, and many others.
WHAT forms are made?	Tubes, rods, bars, flats by extrusion process. More complex parts by machining from pressed slugs before sintering, extremely accurate parts by grinding to required tolerance after furnace sintering.
HOW can you use it?	This remarkable new metal, available in many "grades" to meet specific combinations of imposed conditions, can best be adapted to your high temperature problem by cooperative effort. Our engineers will be glad to discuss how you can get best results from Kentanium.

An Exclusive Development of **KENNAMETAL® Inc.**, Latrobe, Pa.

KENTANIUM

HEAT-RESISTANT, HIGH-STRENGTH, LIGHTWEIGHT
CEMENTED TITANIUM CARBIDE

the problem, it can be broken into three main groups of desired characteristics and requirements. As applied to a dynamic system they may be classed as: (1) input, (2) limiting requirements or specifications, and (3) output. In static systems a slightly different breakdown might be applied.

The three groups can best be explained by considering a typical design problem. In the design of a new type noiseless switch, the specifications can be subdivided as:

1. Input
   Mechanical motion of activation knob. Force required to activate switch
2. Limiting requirements
   Physical size
   Noiseless operation
   Voltage requirements
   Cost—in range of standard switches
   Expected life
   Allowable drop across contacts
   Current rating
   Appearance
3. Output
   Mechanical movements of contacts
   Required time-and-motion characteristics to break arc

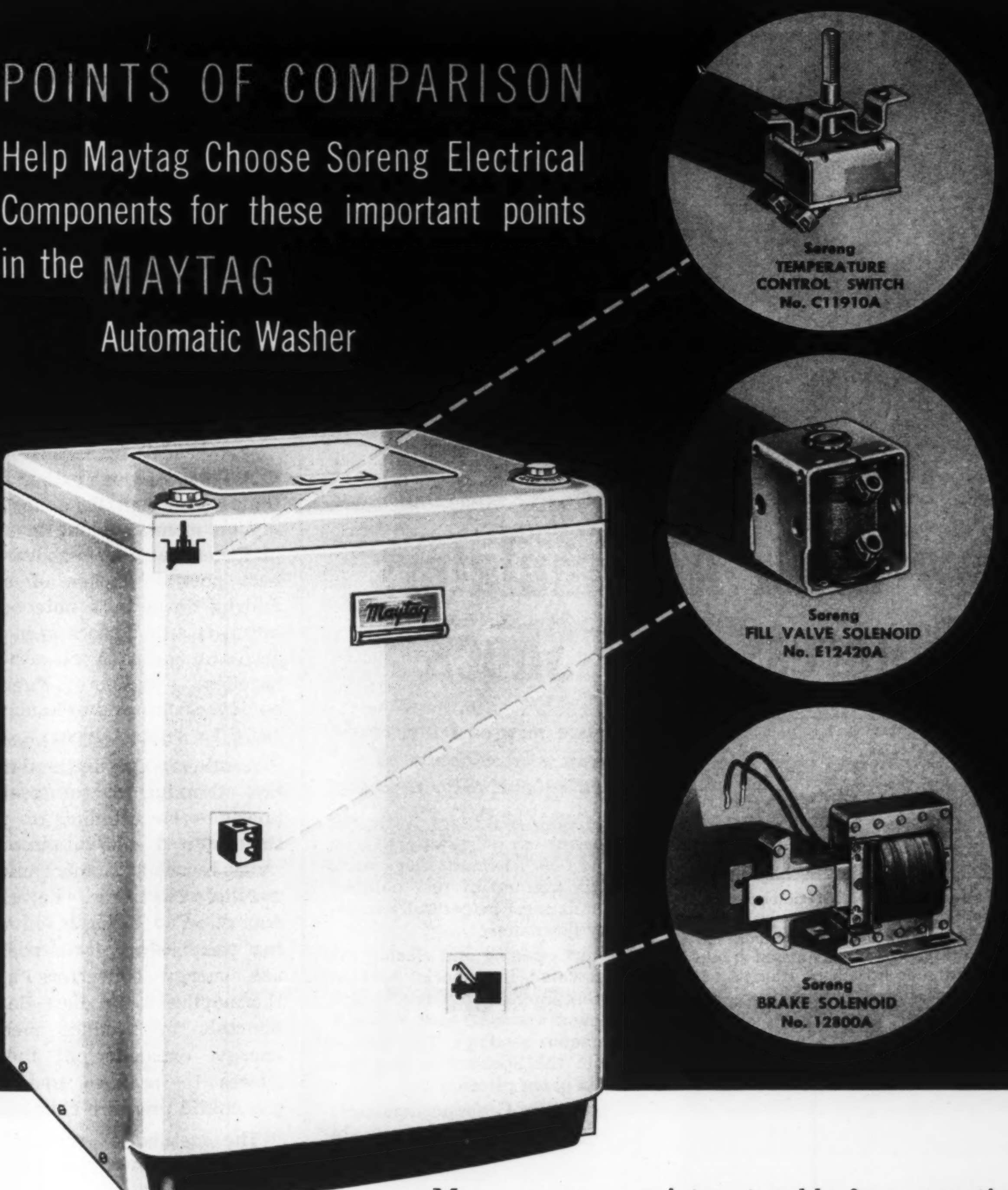
Although not complete and detailed, this serves to show how the groups can be arranged. In a relatively simple design complete quantitative data may not be necessary. Generally though, all dimensions, forces, voltages, and so on should be known quantitatively. If experience has been gained in the field, design sense or "feel" may give adequate measures. But to depend heavily upon mental extrapolation of past designs frequently results in costly failures.

Search for Method: Once the problem is completely analyzed and broken down, means of bridging the gap between input and output are sought. Here experience and background knowledge play the leading role. For in this area a keen mind with a true sense of design curiosity can reveal its vast store of facts on materials, processes, phenomena, devices, mechanisms—and more important—the sources of such information.

Some inventors believe there are at least eight ways of doing every-

POINTS OF COMPARISON

Help Maytag Choose Soreng Electrical Components for these important points in the MAYTAG Automatic Washer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If your product uses electrically-actuated movement . . . if you plan to improve your product with new automatic features . . . it will pay you to let Soreng, with its extensive engineering facilities, help you with your problem. Write us today for information and estimates.

Another example of
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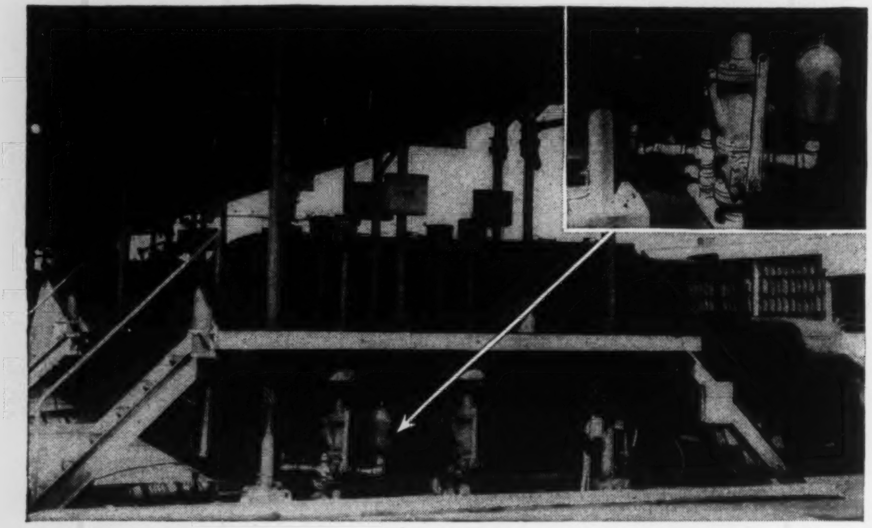
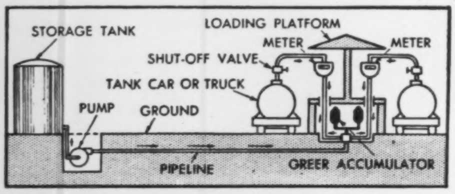
GREER TOPICS **Functions and Applications of the Greer Accumulator**

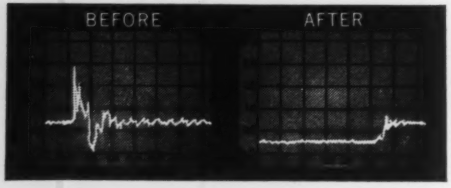


To reduce line shock effectively only two Greer Accumulators were necessary to handle this series of loading racks for petroleum bulk station. Inset: closeup of installation.

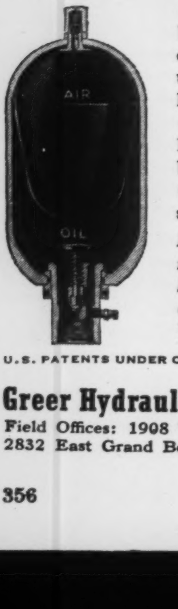
How Greer Accumulators Suppress Line Shock



Above: a schematic of bulk station operation. Below: hydrauliscope gives conclusive evidence that line shock was reduced more than 100% when three valves were closed at once. Write for hydraulic line shock Bulletin 600.



Greer accumulators have many uses as:



(1) Pressure storage chamber for main, auxiliary and emergency power (2) Pressure-volume compensator for leakage and temperature (3) Dispenser of fluids and lubricants (4) Transfer-barrier for fluids and gases (5) Shock absorber for line shock and pump pulsation.

Precision engineered to make any hydraulic system better! Complete data and diagrams in Brochure 301. Write for your free copy.

U.S. PATENTS UNDER OLAER LICENSES

Pressure surges from rapid opening and closing of valves effectively reduced

In loading tank cars or trucks from petroleum bulk stations as an example (see schematic diagram on left), the amount of fuel pumped into a tank must be carefully measured by flowmeters.

By just opening and closing the shut-off valve, line shocks develop with great intensity to cause repetitive flowmeter failures that result in erroneous readings. This can be costly to the operator selling this fuel at a given price.

By installing Greer accumulators that function as perfect shock absorbers, these dangerous pressure surges are made harmless (see hydrauliscope test on left). The elimination of costly flowmeter and pipeline maintenance more than paid for the accumulators within a year.

If your problem is hydraulic line shock, a Greer accumulator is the answer. Let our engineers help you. Call or write today. No obligation.

GREER ACCUMULATORS

Greer Hydraulics Inc. 454 Eighteenth Street, Brooklyn 15, New York
Field Offices: 1908 West Cermak Road, Chicago, Illinois • 25 South Main Street, Dayton, Ohio
2832 East Grand Boulevard, Detroit, Michigan • and sales representatives in all principal cities

thing, and they strive to investigate most of them before making a final selection. In essence this belief is held by all highly creative people. A person is no longer creative when he becomes satisfied that a certain procedure is the only way. The creative mind is an active, nonhabitual mind that always seeks new and better ways of doing things. Not merely content to critcize the present system, such a mind weighs the "other seven" that might be employed.

Thinking Creatively

Because of the number or ways that things can be done, depending on memory alone is often an inefficient way of uncovering the best possible means of solution. Jotting down in a notebook your ideas or any devices seen or conceived in the past will serve as an excellent refresher. Publications on inventions or mechanisms also serve to suggest ideas.

Another way to stimulate creative thinking is to "search for power"—the attempt to perform the required motivation or sensitivity by electric, mechanical, hydraulic, electronic, or chemical means. For example, in measuring temperature it is possible to use energy converters such as thermopiles to produce electricity, bimetals to produce mechanical energy, expansion of fluids and gasses to produce hydraulic or pneumatic pressure changes.

The method of attack for the more complex problems—seldom solved in a single step—becomes one of successive development or synthesis leading from the input to the final output by successive stages. All of the basic or fundamental theories and phenomena that might be applied to the solution should be sought. *The creative engineer must objectively approach this synthesis unhampered by a leaning toward a particular field of engineering.*

As an example of synthesis, consider the design of a thermal cutout for a motor. The input would be heat. And the first part of the synthesis would be a search for all phenomena that respond to application of heat. In the next stage consider the "output" from these indivdual phenomena as the "input" to the next successive stage. This method recently led to the invention of an improved thermal cutout based on a radically new application of the basic concept that mercury will boil when enough heat is applied.

In the search for method it is important that it be unhindered by judicial thinking. All ideas, regardless of how fantastic, should be noted—the imagination works best when unrestrained. Think of the skepticism "conventional thinking" could have introduced in the early contemplation of releasing the almost unbelievable amount of energy available in the atom.

Evaluation and Selection of Method: In this step each system evaluated must be thoroughly considered as it affects all the design requirements. Particular emphasis should be placed on time and economic factors. Each problem will largely determine the weight a given factor carries in the final selection. Some of the factors that affect the evaluation and selection of a method of solving a design problem are the following:

Cost
Development program
Finished product
Time Allowed
For development
For reaching production stage
Accuracy
Sufficient for specifications
Better than specifications
Power Requirements
Space Requirements
Tools and Machines Available
Adequate for production
New machines required
Materials Required
Common and easily obtained
New or scarce materials
Production Difficulties
Standard tolerances and procedures
High tolerances and involved processes
Patent Difficulties
Patents held by manufacturer
Patents held by competitors
Appearance
Complexity
Skill of operating personnel
Skill of maintenance personnel
Consequences of Faulty Operation

(*Continued on Page* 362)

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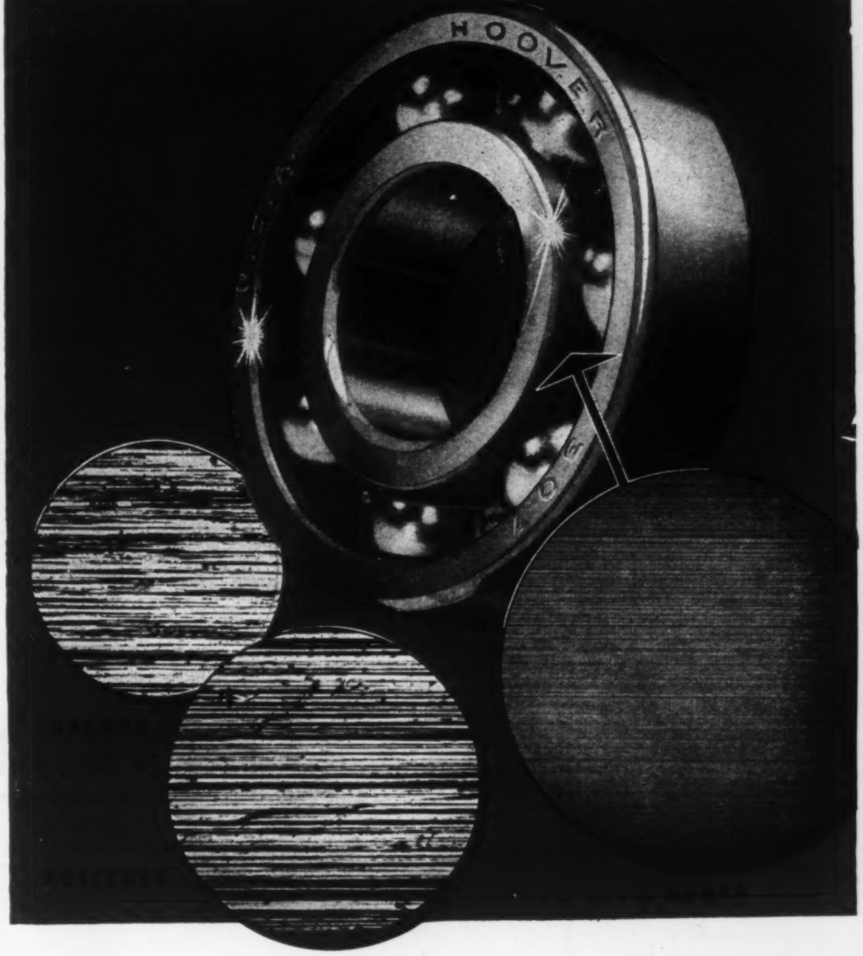
HONED RACEWAYS



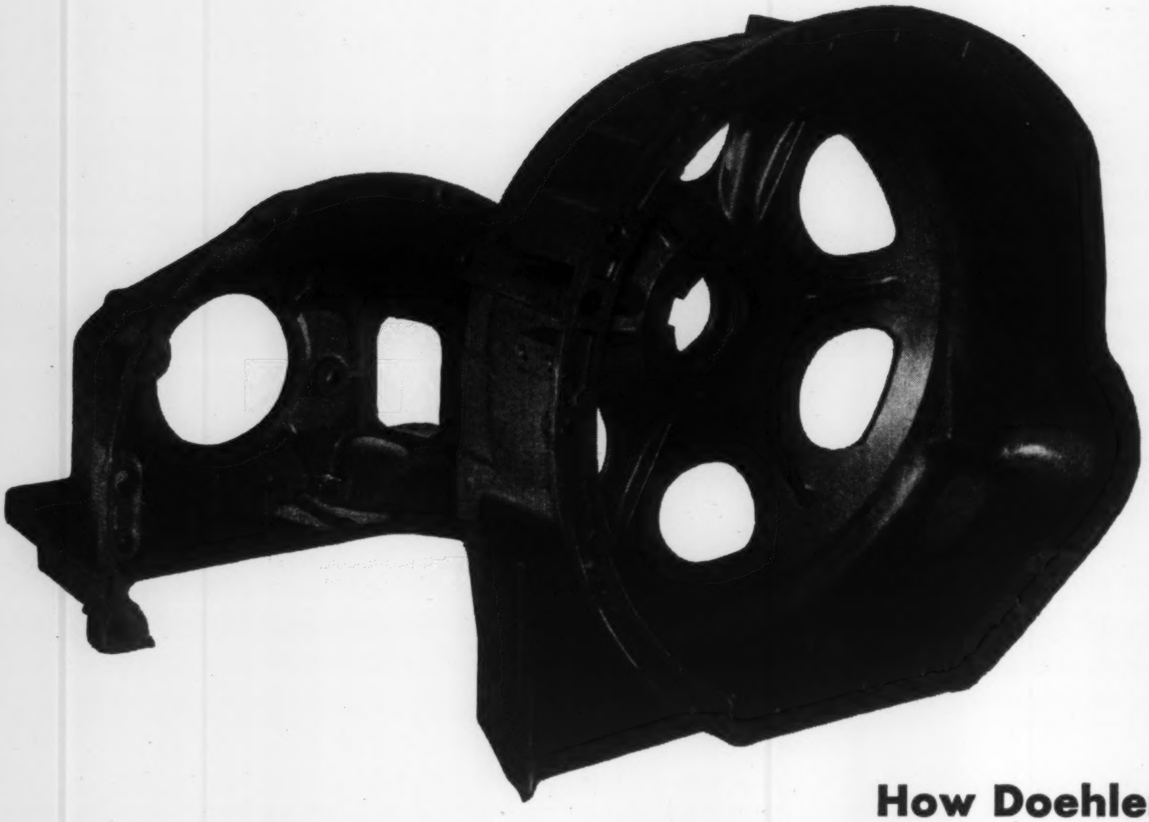
exclusive with
HOOVER BALL BEARINGS

The photographs reproduced above are magnified one hundred times so you can see the difference between ground, polished and honed raceways. The process and the special machines for the honing operation are exclusive, patented, Hoover developments. Honing by Hoover goes far beyond grinding and polishing to achieve a surface that assures amazing quietness plus *longer bearing life . . . and greater load capacity.* That's why Hoover Ball Bearings are the choice of distinguished American manufacturers of fine machines and equipment.

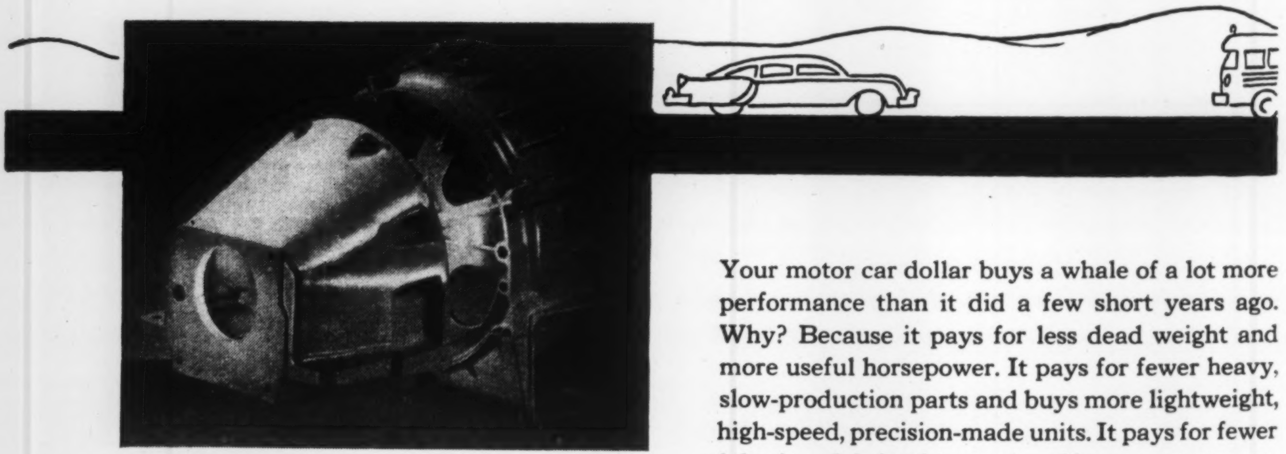
The Hoover Engineering Manual will be mailed free to engineering and purchasing executives requesting a copy on their business letterhead.

THE ARISTOCRAT OF BEARINGS

HOOVER BALL and BEARING CO.
Ann Arbor, Michigan



How Doehler-Jarvis halve the weight and

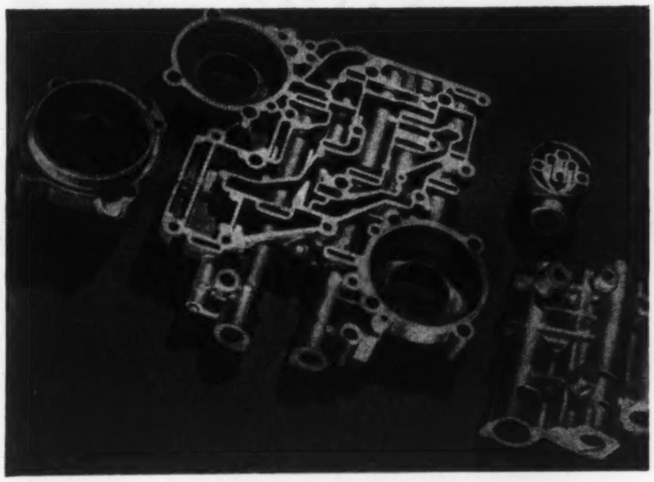


These torque converter and clutch housings are light, sound and strong. They withstand great vibrational stresses and the jarring and jouncing encountered in endless miles of "shift-free" motoring. As cast by Doehler-Jarvis, these housings provide many economies in machining costs. For one example, the long oil holes in the torque converter housing are cast-in.

Your motor car dollar buys a whale of a lot more performance than it did a few short years ago. Why? Because it pays for less dead weight and more useful horsepower. It pays for fewer heavy, slow-production parts and buys more lightweight, high-speed, precision-made units. It pays for fewer laborious fabrication steps and buys more streamlined assemblies of formed-to-fit parts.

As a case in point, consider the automatic transmission. It has become progressively more efficient, lighter in weight, part for part – and less expensive to own and operate.

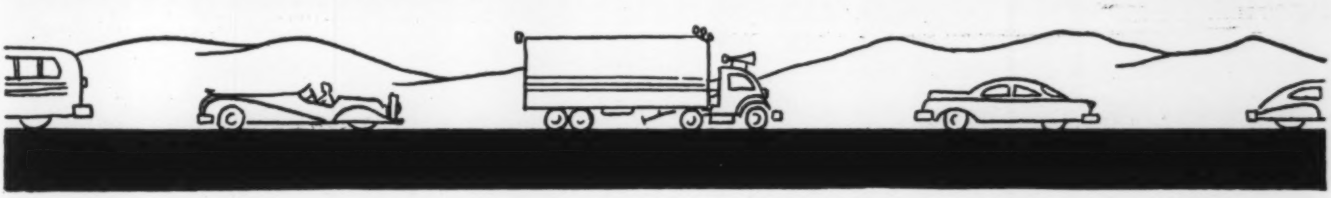
These improvements have been made possible to a great extent by the use of die cast parts, many of which are produced by Doehler-Jarvis in close cooperation with motor car makers.



Valve castings used in an automatic transmission. These parts are among the most intricate of the multitude of die castings made by Doehler-Jarvis. Obviously extreme dimensional accuracy is required for proper fit and functioning of all valve components.

Helped Motor Car Makers

lower the cost of heavy duty housings



A prime example of this teamwork between the customer's design and engineering staffs and those of Doehler-Jarvis is the set of housings – torque converter and clutch – illustrated.

These are truly heavy duty parts. Before Doehler-Jarvis entered the picture they weighed together about 50 pounds and required considerable working-over and machining prior to assembly. The Doehler-Jarvis aluminum housings weigh about 23 pounds and require a minimum of handling before assembly.

This is but one example of how the Doehler-Jarvis organization, with resources and resourcefulness developed during a half century of die casting, works hand-in-hand with makers of metal products–in the automotive, household appliance, office machine, electrical merchandise and many other important industries.

Call in Doehler-Jarvis when you are faced with problems in the design and procurement of lighter weight, lower cost, more efficient metal parts.

Doehler-Jarvis
Division
of
National Lead Company*
General Offices: Toledo 1, Ohio

*Reg. U. S. Pat. Off.

Pioneer
PUMPS
from 0 to 174 gpm
850 to 3450 rpm

PUMP CAPACITY CHARTS

Pioneer
IMPELLER PUMPS
are performance tested for life-time delivery within 5% of catalog rating.

Ideal for:
- Lubricants
- Coolants
- Abrasive Liquids
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Ask for Complete Catalog of Pumps and Accessories
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Division of
DETROIT HARVESTER
Company
2750 Guardian Bldg. · Detroit 26, Mich.
(FACTORY—Paris, Kentucky)

Design Abstracts

(*Continued from Page* 359)

Versatility of Application
Coverage of field desired
Supersedes predecessor
Supersedes Competitors' device
Operating Environment Effects
Corrosive atmosphere
Dust
Vibration and shock
Safety Features

Not all of these items apply to all development and design problems. In the early stages of a development program the requirement of new tools and machines may often be set aside until samples have been built and tested. Test results can then help determine whether retooling is feasible. The decison for timing all the factors of evaluation into the development program rests with the engineer. He may even recommend a change in the specifications if his evaluation shows that a better product would result.

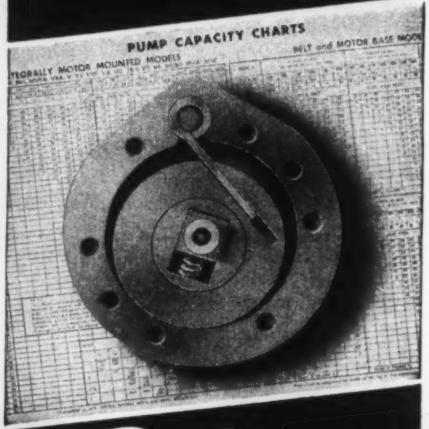
Sometimes the evaluation of the methods will show the necessity of redefining the problem and of making a new search for method. Preliminary tests and mathematical calculations should be made to verify expected results. Inadequate application of engineering fundamentals in the early stages will usually result in the loss of time, money, and prestige.

Solution: When working out the details of the method selected, the various steps are repeated on the components required. Thus the phases are used simultaneously in other than simple problems, and each portion of the design is evaluated as the details are solved. Component designs should be checked with the specification of the overall design and the listed requirements of the component.

When the problem involves primarily test work or calculation, it should be remembered that numbers obtained are seldom a saleable item but rather pose the question: "So what?" In other words, the job is not finished until it can show how the results affect the finished product. Having lived with the details of the analysis or test, it should be easy to make recommendations to improve quality and price of the device.

Strive to meet all specifications

Rollway
PUMPS
from 1/8 to 60 gpm
200 to 500 rpm



Rollway
POSITIVE DISPLACEMENT PUMPS
are performance tested for life-time-delivery within 5% of catalog rating.

Ideal for:
- Lubricants
- Coolants
- Fluids with Lubricating Properties
- Gear Boxes
- Industrial Transmissions and Speed Reducers
- Mounting above Liquid Levels
- Operation from 15 to 35 psi

Ask for Complete Catalog of Pumps and Accessories
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Division of
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(FACTORY—Paris, Kentucky)

MAXITORQ
CARLYLE JOHNSON MANCHESTER
THIN
BLADES
Gillette
Gillette
K-34
BRUSHLESS SHAVING CREAM

MAXITORQ

Overload Release CLUTCH

minimizes machine Down-Time

AT THE GILLETTE SAFETY RAZOR CO.

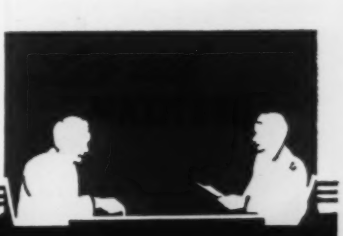
The Maxitorq automatic Overload Release Clutch was designed especially to protect high-speed machinery, and we are gratified to have testimonials such as the following:

> "The Gillette Safety Razor Company chose the Maxitorq Overload Release Clutch to protect a section of their blade and shaving cream packaging machines against costly down-time due to unpredictable machine jams.
>
> "Over a period of a year, wrapping millions of blades per week, Maxitorq Clutches have eliminated machine down-time except in a few minor instances. Thus, more constant production has been maintained in the packaging department."

When an accidental overload occurs, the clutch automatically releases, stopping the machine, preventing damage to machine and product. When the jammed condition has been cleared, the clutch is re-engaged and the machine is again in operation. By means of a simple finger-tip adjustment, the clutch is set to transmit the normal running load.

There are six sizes, ¼ to 5 h.p. @ 100 r.p.m.; max. working torque ft. lbs. 13 to 263. Maxitorq "floating" discs prevent heating in neutral, and all assembly, take-apart, and adjustments are manual; disengagement is instant and complete. Submit your clutch problems to our engineers for practical solutions.

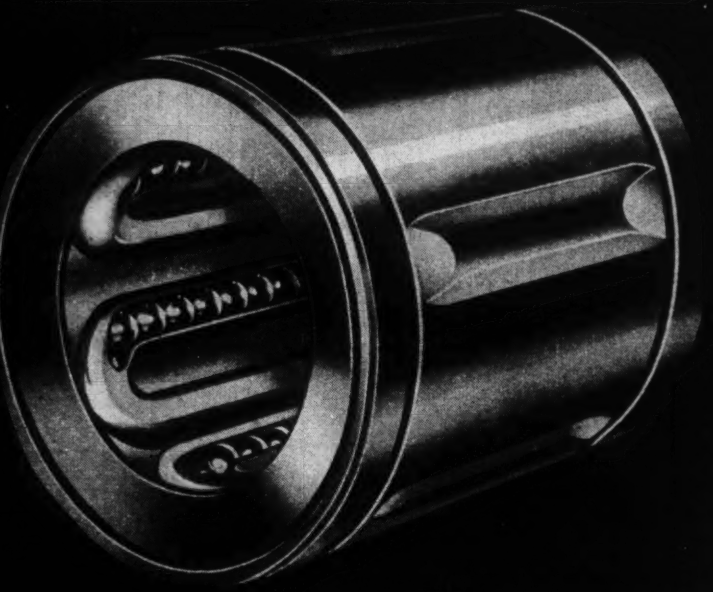
SEND FOR CATALOG NO. MD-10.



8CJ53

THE CARLYLE JOHNSON MACHINE COMPANY
MANCHESTER • CONNECTICUT

BALL BUSHING



The BALL BEARING for your

LINEAR MOTIONS

Sliding linear motions are nearly always troublesome. Thousands of progressive engineers have solved this problem by application of the Precision Series A or Low-Cost Series B BALL BUSHINGS.

Alert designers can now make tremendous improvements in their products by using BALL BUSHINGS on guide rods, reciprocating shafts, push-pull actions, or for support of any mechanism that is moved or shifted in a straight line.

Improve your product. Up-date your design and performance with BALL BUSHINGS!

Now manufactured for ¼", ½", ¾", 1", 1½", 2" and 2½" shaft diameters.

LOW FRICTION · LOW MAINTENANCE
ELIMINATES BINDING AND CHATTER
SOLVES SLIDING LUBRICATION PROBLEMS
LONG LIFE · LASTING ALIGNMENT

Progressive Manufacturers Use Ball Bushings
—A Major Improvement at a Minor Cost

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Write for descriptive literature and the name of our representative in your city.

Also manufacturers of NYLINED Bearings — DuPont NYLON within a metal sleeve—for rotation and reciprocation.

and time schedules by proper planning. Have parts completed in sequence that will best permit partial testing. Do not delay design and construction of one part that will needlessly prevent proper testing of many other parts. Keep in mind that instructions for manufacturing and operation can be as important as the design itself. The user may not know exactly how to operate your brainchild unless you tell him.

Little details are important too—nuts, bolts, washers, and bearings are part of the design. Perhaps the draftsmen can select these for you, but it is your responsibility to check and approve all of these "minor" details. Little things, like insufficient wrench clearance to requiring special adjustment tools can destroy the market for a particular model. In the final analysis, the proof of the solution is in customer acceptance and profit to the company.

From an article entitled "Solve Design Problems with a Creative Approach" appearing in the General Electric Review for July, 1953.

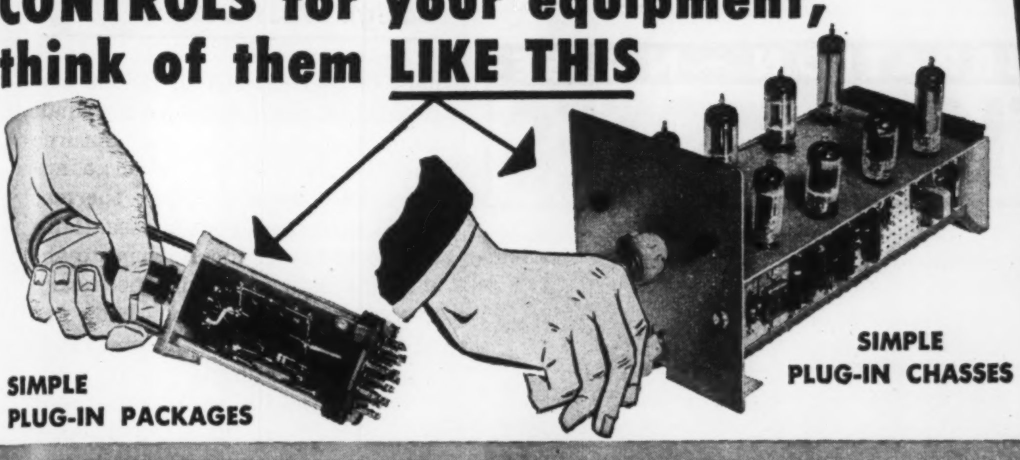
Material Behavior Under Thermal Loads

By S. S. Manson
Lewis Flight Propulsion Laboratory
Cleveland, O.

WHEN a material is subjected to temperature gradient or when a composite material consisting of two or more materials of different coefficients of expansion is heated either uniformly or nonuniformly, the various fibers tend to expand different amounts in accord with their individual temperatures and temperature coefficients of expansion. To enable the body to remain continuous, rather than allowing each fiber to expand individually, a system of thermal and associated stresses may be introduced depending upon the shape of the body and the temperature distribution. If the material cannot withstand the stresses and strains, rupture may occur.

Brittle and ductile materials react in considerably different man-

In visualizing AUTOMATIC ELECTRONIC CONTROLS for your equipment, think of them LIKE THIS


SIMPLE
PLUG-IN PACKAGES
SIMPLE
PLUG-IN CHASSES

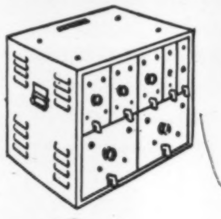
Are your prospects afraid of the "Little Black Box?"

Your wonderful new Electronic Controls may mean the death of a sale — unless the cautious buyer sees that his own personnel can locate and correct Control troubles on the spot.

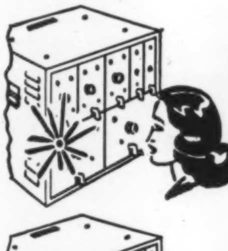
Any electronic equipment can now be subdivided into simple plug-in units that for the first time assure your users RELIABILITY IN SERVICE

(The User's own personnel can locate and correct most troubles on the spot)

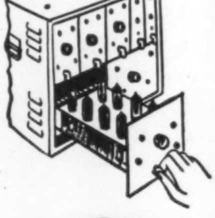
Here are the bold new Standards:



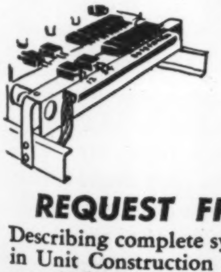
① Circuitry subdivided, function by function into plug-in units.



② Tiny telltales spot trouble instantly.



③ Plug in replacement spares in 30 seconds.



④ All leads brought to single accessible point of check — all numbered, color-coded — so layman can make first-level tests.

REQUEST FREE HANDBOOK

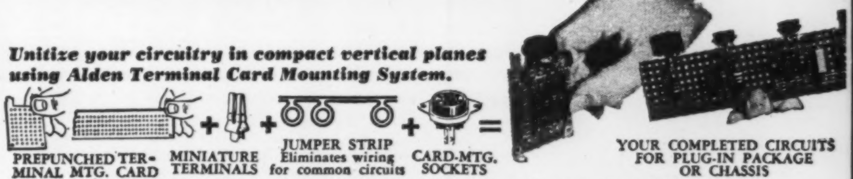
Describing complete system of Plug-in Unit Construction and Components. 226 pages and many Planning Sheets.

ideas
techniques
designs

Here's how to get them:

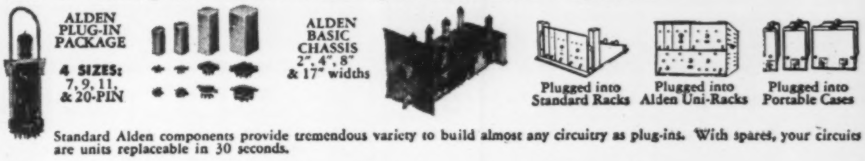
IT'S AS SIMPLE AS THIS –

1. *Unitize your circuitry in compact vertical planes using Alden Terminal Card Mounting System.*


PREPUNCHED TERMINAL MTG. CARD
MINIATURE TERMINALS
JUMPER STRIP Eliminates wiring for common circuits
CARD-MTG. SOCKETS
YOUR COMPLETED CIRCUITS FOR PLUG-IN PACKAGE OR CHASSIS

You can use Alden Terminal Mounting Card with Alden Miniature Terminals, Jumper Strip and Sockets staked to accommodate any circuitry — making complete units ready for housing. Components snap into unique Alden Terminals, are held ready for soldering.

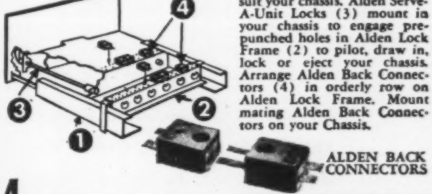
2. To mount this vertical circuitry, ALDEN PLUG-IN PACKAGES AND BASIC CHASSIS give tremendous variety with standard components


ALDEN PLUG-IN PACKAGE
4 SIZES: 7, 9, 11, & 20-PIN
ALDEN BASIC CHASSIS 2", 4", 8" & 17" widths
Plugged into Standard Racks
Plugged into Alden Uni-Racks
Plugged into Portable Cases

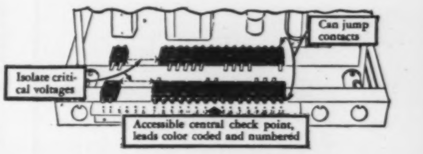
Standard Alden components provide tremendous variety to build almost any circuitry as plug-ins. With spares, your circuits are units replaceable in 30 seconds.

3. Give chassis easily traceable interconnects and 30-second replacement with ALDEN SERVE-A-UNIT KIT

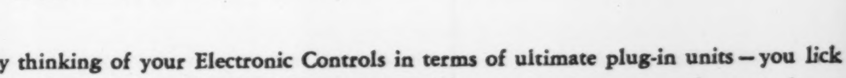
IT'S AS SIMPLE AS THIS Arrange Alden Side Rails (1) and Alden Lock Frame (2) to suit your chassis. Alden Serve-A-Unit Locks (3) mount in your chassis to engage prepunched holes in Alden Lock Frame (2) to pilot, draw in, lock or eject your chassis. Arrange Alden Back Connectors (4) in orderly row on Alden Lock Frame. Mount mating Alden Back Connectors on your Chassis.


④
③
②
①
ALDEN BACK CONNECTORS

GIVING YOU 1) Chassis that plugs in, locks and ejects with half turn of the wrist. 2) leads so beautifully organized, accessible and identified that non-technical personnel can service.


Can jump contacts
Isolate critical voltages
Accessible central check point, leads color coded and numbered

4. *Assign to each unit ALDEN SENSING ELEMENTS — to spot trouble instantly:*


MINIATURE TEST JACK
MINIATURE INDICATING LIGHT
MINIATURE INDICATING FUSE HOLDER

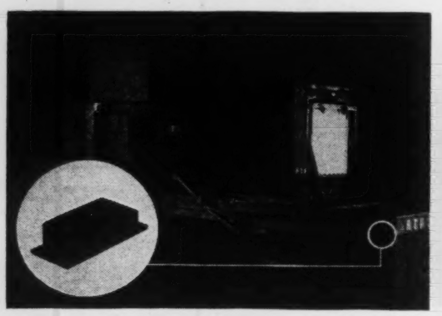
Compact front panel easily mounts 6 tiny Alden Sensing Elements — specifically designed to lick the problem of small space.

By thinking of your Electronic Controls in terms of ultimate plug-in units — you lick the problem of RELIABILITY IN SERVICE for your Customer . . . and you wash out problems of Design, Manufacture and Procurement for all concerned.

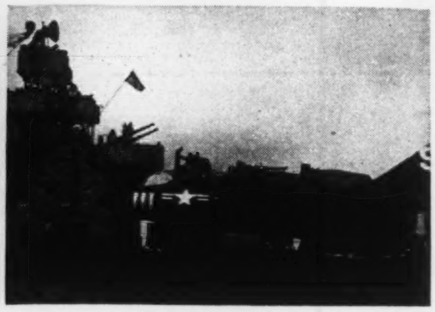
NA-ALD **ALDEN PRODUCTS CO.** 149 N. Main St., Brockton 64, Mass.

SHOCK – VIBRATION – NOISE

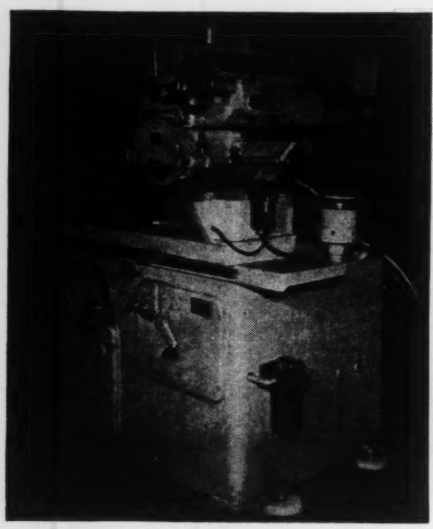
ISOLATION NOTES



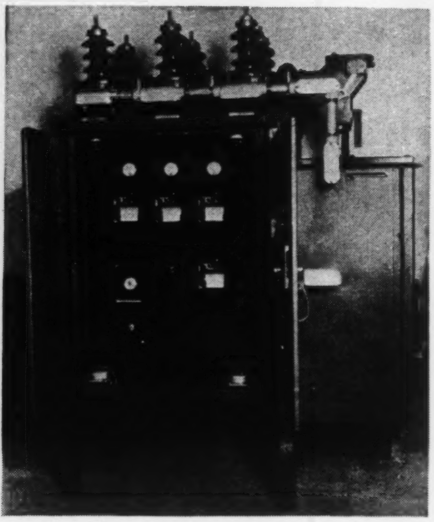
A PHOTO-ENGRAVER'S CAMERA "floated" on Barrymounts, is isolated from floor vibrations. Result: sharper images and faster operation.



MEET DEMANDS OF MILITARY SERVICE Barry unit vibration isolators and mounting bases protect delicate electronic equipment in military aircraft and in guided missiles.



GRINDER ACCURACY PROTECTED Barrymounts, used to isolate grinders from building-borne vibration, eliminate chatter marks. Result: higher output and better finish.



INSTRUMENT AND CONTROL PANELS mounted on Barry isolators, are unaffected by vibration from nearby heavy machinery. Result: sensitive adjustments "stay put," and frequent recalibrations are avoided.

IN ANY FIELD OF MILITARY OR INDUSTRIAL INTEREST the wide range of Barry products, and the experience of Barry engineers, can help you solve shock, vibration, and noise problems. Call our nearby sales representative, or write directly to us.

THE BARRY CORP.

722 PLEASANT ST., WATERTOWN 72, MASSACHUSETTS

SALES REPRESENTATIVES IN

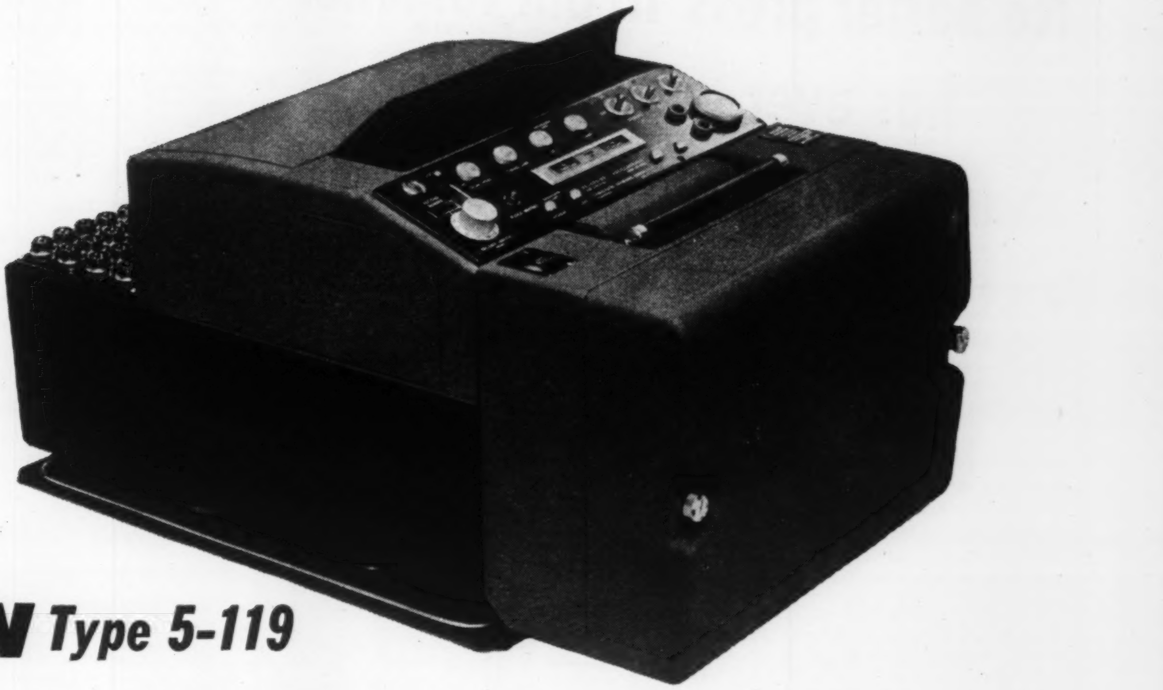
Atlanta Baltimore Chicago Cleveland Dallas Dayton Detroit Los Angeles Minneapolis New York
Philadelphia Phoenix Rochester St. Louis San Francisco Seattle Toronto Washington

ners to thermal stress. Brittle materials can endure only a very small amount of strain before rupture; ductile materials can undergo appreciable strain. Since thermal stress behavior depends essentially on the ability of the material to absorb the induced strains necessary to maintain a continuous body upon the application of thermal gradient, brittle materials cannot readily withstand these superimposed strains without inducing enough stress to cause rupture; ductile materials, on the other hand, can usually withstand these additional strains, but may ultimately fail if subjected to a number of cycles of imposed temperature.

The problem of thermal stress is of great importance in current high-power engines. The present trend toward increasing temperatures has necessitated the use of refractory materials capable of withstanding much higher temperatures than normal engineering materials. One salient property of these materials is lack of ductility. For this reason, thermal stress is one of the most important design criteria in the application of these materials. Thermal stress is also currently receiving considerable attention in connection with ductile materials since there is considerable evidence that failure of many ductile engine components can be attributed to thermal cycling. The problem of high-speed flight, with attendant increases of temperature and temperature gradients in aircraft bodies, has further generated concern over the significance of thermal stress in ductile materials.

Thermal stress and shock: These two terms may be distinguished by the fact that in thermal shock the thermal stresses are produced by transient temperature gradients, usually sudden ones. For example, if a body originally at one uniform temperature is suddenly immersed in a medium of different temperature, a condition of thermal shock is introduced. At any instant the stresses are determined by the temperature distribution and are no different from what they would be if this temperature distribution could be obtained in the steady-state condition. But the temperature gradients that can be estab-

YOU helped create this superior Recording Oscillograph



NEW Type 5-119

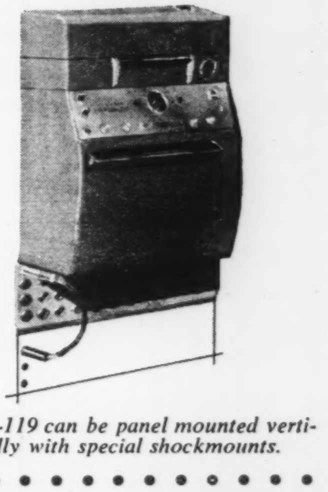
CONSOLIDATED's new Type 5-119 Oscillograph was designed and built to customer specifications. Many major users were interviewed by our design engineers to determine the features desired in a "perfect" instrument. Foremost demand was for great dependability. Second need indicated was for high trace capacity.

Dependability is achieved by extensive warning and test circuits and by reserve lamps which assure continuous recording in the event of lamp burn-out. Indicators warn immediately of any condition which could cause data loss, while additional circuits permit quick testing of the warning system. Design of the instrument assures reliable operation under the most rigorous environmental conditions.

Standard models provide either 36 or 50 traces. Consolidated's new Series 7-300 Galvanometers provide frequency response flat to 3000 cps. Standard record width of 12″ greatly simplifies record interpretation. Only after several prototypes were successfully tested under actual field conditions did we go into production on the 5-119—the new recording oscillograph leader. Write for Bulletin CEC 1536-X3.

SPECIFICATIONS

TRACE CAPACITY	36 or 50-trace models available
TRACE IDENTIFICATION	repeated, sequential trace breaks
RECORD WIDTH	12″ standard; narrower widths adaptable
RECORD MAGAZINE	removable, integral type; holds 250′ paper or film
RECORD SPEEDS	0.10 to 100 inches per sec. through quick-change gears, instantaneous switch-actuated, 10:1 speed jump
SCANNING SYSTEM	ground-glass screen and adjustable motor-driven polygon mirror; timing lines show on viewing screen
REMOTE OPERATION	accessory control unit with all essential controls & indicators
TIMING PROVISIONS	0.10 and/or 0.01 sec. lines photographed across record
EVENT NUMBERING	high-speed flash system operates as rapidly as one number per sec.
POWER REQUIREMENTS	115 volt, 60 cycle and 26 volt d-c models
INPUT PROVISIONS	all connectors on one rear deck; individual galvanometer plugs
CONTROL PANEL	all controls and indicators on single panel
ACCESSIBILITY	all adjustments can be made from one surface



The 5-119 can be panel mounted vertically with special shockmounts.

Consolidated Engineering
CORPORATION
300 North Sierra Madre Villa, Pasadena 15, California

Sales and Service through **CEC INSTRUMENTS, INC.,**
a subsidiary with offices in: Pasadena, New York, Chicago, Washington, D. C., Philadelphia, Dallas.

analytical instruments for science and industry

Recording Oscillographs

The Type 5-119 is the newest of 7 Consolidated Oscillographs ranging from 9 to 50 channel capacity. These versatile instruments simultaneously record any physical phenomena that can be transformed into electrical impulses. All measurements are obtained in clear, permanent form during the same operational cycle for future detailed analysis.

lished in the transient state are generally much higher than those that occur in the steady state, and hence thermal shock is important relative to ordinary thermal stress because of the higher stress that can be induced. Another distinction between thermal stress and thermal shock is that in the latter stress is applied at a rapid rate, and many materials are affected by the rate at which load is applied. Some materials are embrittled by rapid application of stress and therefore may not be able to withstand a thermal shock stress which if applied slowly could readily be absorbed.

Thermal Stress in Welding: The problem of thermal stress and thermal shock is one of extreme importance in the field of welding. Here, dissimilar metals are joined together, these dissimilar metals being either parts welded together or the weld metal. Differential thermal expansion between the different metals, cracks initiated during the welding, friction oxidation between the welded parts, and metallurgical interaction between the dissimilar materials all contribute to loss of thermal shock resistance.

Thermal Fatigue: It is also necessary to distinguish between a single cycle of thermal stress and thermal fatigue. When failure is caused by the application of several similar thermal stress cycles, rather than a single cycle, the process is referred to as thermal fatigue. The processes that take place in a body in successive cycles of stress application are extremely complex; the mechanism leading to cyclic failure is as yet incompletely understood. In most of the basic work, therefore, attention is directed at the conditions under which failure will occur in one cycle merely because this case lends itself to analysis. The problem of thermal fatigue is, of course, a most important one in engineering application. Thermal fatigue is very complex in brittle materials; it is even more complex in ductile materials as a result of metallurgical changes associated with plastic flow.

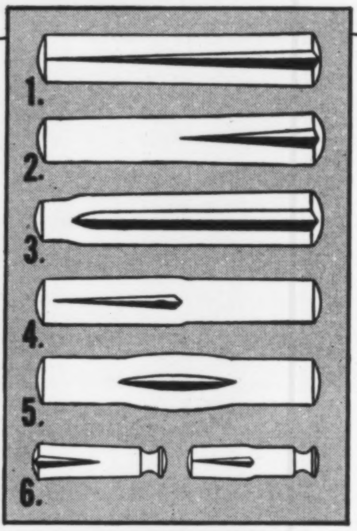
Effect of Ductility: One of the

No better press fit pin fastener has ever been devised than the original GROOV-PIN

The Groov-Pin is primarily a cylindrical pin cut from bar or coil stock. Longitudinal grooves are rolled or pressed into the body to deform the stock within controlled standard limits.

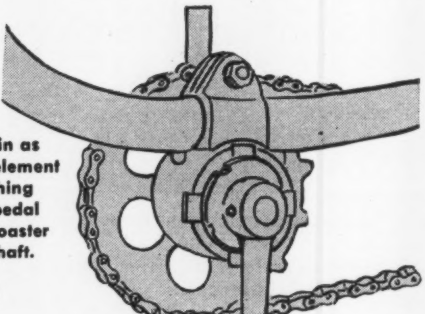
When the Groov-Pin is forced into a drilled hole of correct diameter, the constraining action of the hole wall causes the displaced material to flow back and make a locking fit within its elastic range. Resiliency of the pin stock makes it practicable to use the same pin repeatedly.

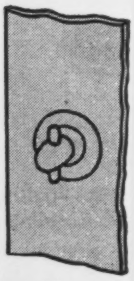
The Groov-Pin is simple in design, efficient, economical both in price and in cost of application, and it is versatile in its uses. This combination of advantages has never been surpassed by any other pin fastening. It is true even though Groov-Pins have been in use for over a quarter-century, essentially in their present form from the beginning. Like the common pin or nail the original design of the Groov-Pin was fundamentally perfect. Therefore, improvement has been impossible. Groov-Pins are assembled in straight drilled holes. No tapping, reaming, peening or milling are required. They can be driven by hand hammer, air cylinder or hydraulic press.

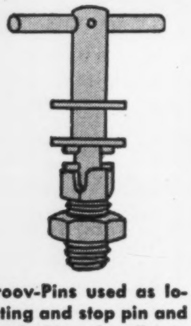


1. Full length taper Groov-Pin.
2. Half length taper Groov-Pin.
3. Full length parallel Groov-Pin.
4. Half length reverse taper Groov-Pin.
5. Center Groov-Pin.
6. Half length taper and reverse taper Groov-Pin with annular grooves for spring retention.

Heavy-duty hinged bolt assembly with Groov-Pin as hinge pin.


Groov-Pin as fastening element in attaching bicycle pedal arms to coaster brake shaft.


Groov-Pin used as cross pin in stud of cowling fastener.


Groov-Pins used as locating and stop pin and for locking handle in pressure relief valve stem.

Groov-Pin used as heavy duty cotters on heavy chain links.

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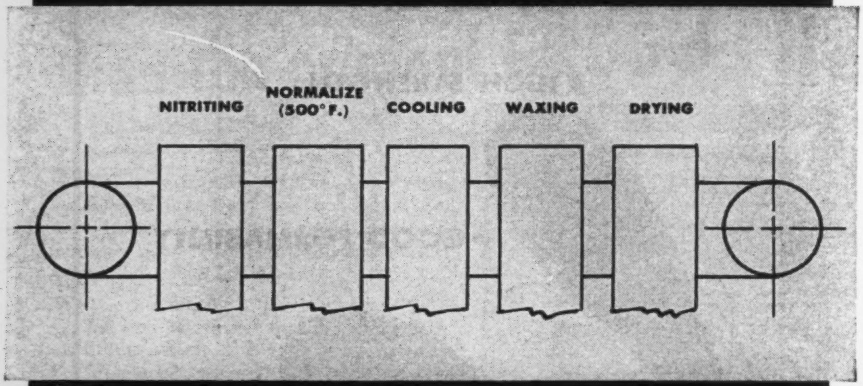

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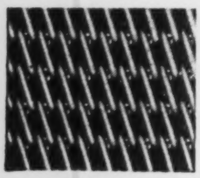

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most important characteristics which affect the thermal shock resistance of a material is ductility. If the environmental temperature and atmosphere are not such as to destroy ductility by embrittlement, the ductile material will withstand considerably more severe thermal shocks than brittle materials of comparable tensile strength and other mechanical and thermal properties. One of the concepts that led to the development of the metal-ceramic combinations known as ceramals was the thought that the metal would impart ductility to the combination, and thereby, good thermal shock resistance. In practice this hope has not been fully substantiated. Despite appreciable metal content, many ceramals show no measurable ductility at room temperature and only very minor ductility at high temperature. But even this small ductility greatly improves the thermal shock resistance. It is believed that ceramals do show some ductility in thermal shock tests at high temperature.

In brittle materials, the fact that stress is proportional to strain makes an analytical treatment possible; and the fact that failure can be achieved in one stress cycle makes it possible to obtain valid experimental results for correlation with theory. When ductile materials are considered, the problem becomes more complex. First, stress is no longer proportional to strain and therefore stress equations cannot readily be solved. Only a few problems involving plastic flow of ductile materials under thermal stress have been solved. Secondly, it is rarely possible to obtain failure in one cycle which is possible in brittle materials. The failure process is a progressive one and material deterioration occurs during and in between applications of thermal shock. Metallurgy of the material becomes a predominating factor. Thus, with ductile materials the data are usually presented in the form of number of shock cycles withstood under a given set of conditions.

Effect of Conductivity: Although under very unusual circumstances, high conductivity may be undesirable, the usual case is that good conductivity improves thermal shock resistance. Not only does good conductivity generally reduce stresses during the thermal shock process, but it frequently reduces working temperatures and hence brings many metals into an operating temperature range where their strength is greater.

In brittle materials it appears that under certain conditions good conductivity can be a detriment rather than an asset. A simple physical explanation for this phenomenon can readily be given: In the poor conductors only the fibers very near the surface are affected by the applied heating for the first very short interval of shock application. High stresses are thus induced in the surface, but these stresses are compressive and may not cause failure. The induced tensile stress at the center is low because the high compression of only a few fibers must be counteracted by the main bulk of the plate. For the better conductors the effect of the surface heating is felt much more rapidly throughout the plate. The compressive stress at the surface may be lower at a given time, but more fibers are under compressive stress, and hence the induced tensile stress at the center is higher. The exact relative merit of materials with different conductivities depends upon the exact heating time, and no simple general formula has been found. Also it must be recognized that in the limit the trend must be reversed. Obviously a material with infinite conductivity must be the most desirable because in such a material no temperature gradients could be established, and no thermal stresses developed.

Thermal Cycling: One of the mechanisms associated with the ultimate failure of ductile materials in thermal cycling is plastic flow. Fatigue is generally thought of as a process of first initiating and then propagating a crack until ultimate rupture occurs. In the case of thermal stress cycling, the crack may not have to be initiated by the plastic flow; rather it may

(*Continued on page 376*)

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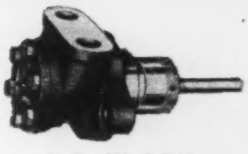

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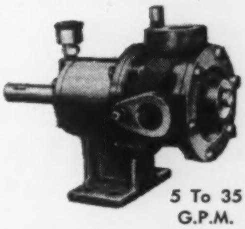

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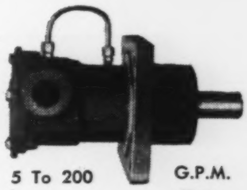

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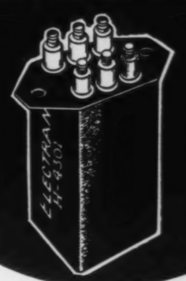

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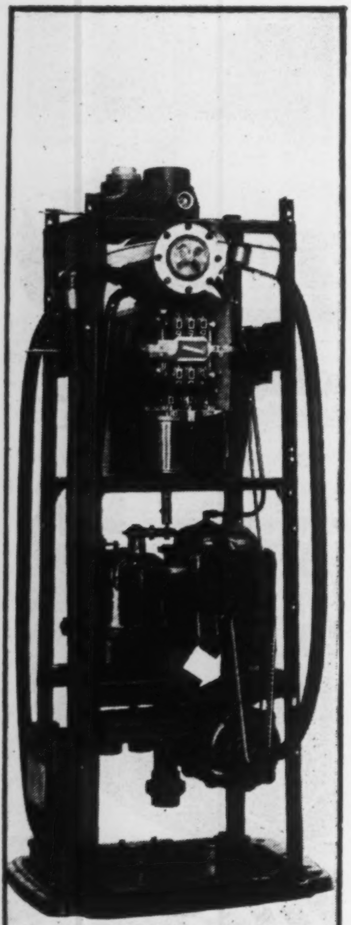

WHEN PERFECT SYNCHRONIZATION or elimination of slippage is important, the Gilmer "Timing" Belt drive affords many unique advantages. Here, however, is an application for which the "Timing" Belt drive was chosen solely for its *nearly 100% efficiency in transmitting power* . . . and the *savings* which that efficiency made possible!

In extensive tests, prior to adoption of the "Timing" Belt drive to replace the V-belt drive between motor and pump, engineers of Tokheim Oil Tank & Pump Company found that the "Timing" Belt drive:

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Various users of Gilmer "Timing" Belt drives who have made dynamometer tests report no appreciable difference between motor output and power delivered to the driven shaft. Such superior efficiency stems from the fact that "Timing" Belt drives do not rely on surface friction or belt tension for grip. They have no friction-creating joints, no metal-to-metal contacts, no slippage loss, no lubricant drag and impose minimum loads on bearings.

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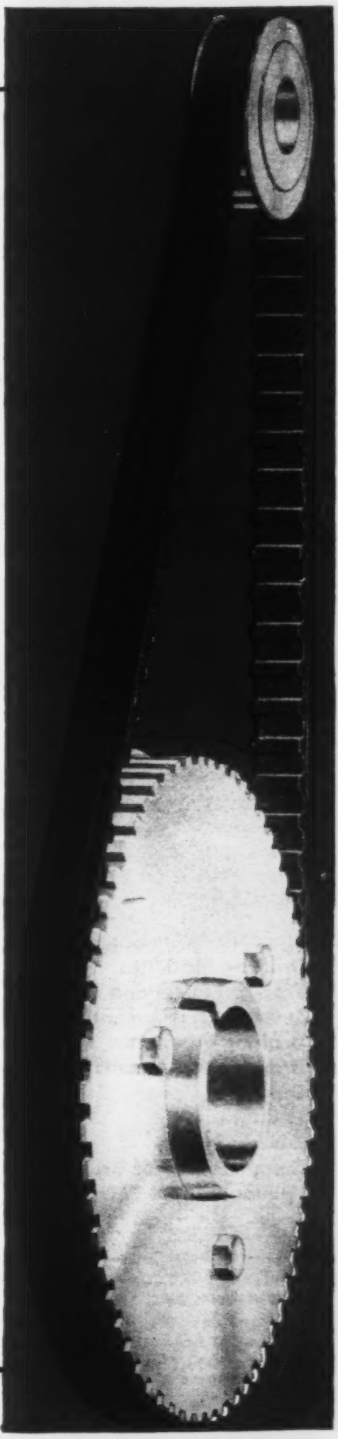

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- **Maintains precise synchronization ("timing") between shafts.**
- **Provides speed ratios as high as 15 to 1 in a single step.**
- **Operates satisfactorily at speeds from inches per hour to 15,000 fpm.**
- **Permits use of very small diameter pulleys for ultra-compact drives.**
- **Has nearly 100% mechanical efficiency.**
- **Needs no initial tension. Lighter bearing loads permit lighter bearings.**
- **Does not stretch or lengthen with use; requires no take-up.**
- **Can be designed for zero backlash.**
- **Capacity ranges from 1/100 to 300 horsepower.**

These are but a few of the unique features of this amazing tooth-grip belt drive that is already in successful use on hundreds of thousands of machines. Consult your local NYB&P Distributor—or write direct for the new 76-page Gilmer "Timing" Belt Standard Drive Manual listing hundreds of drives now available promptly *from stock.* Address Gilmer "Timing" Belt Division of New York Belting and Packing Co., Tacony, Philadelphia 35, Pa., or phone Devonshire 3-7400.

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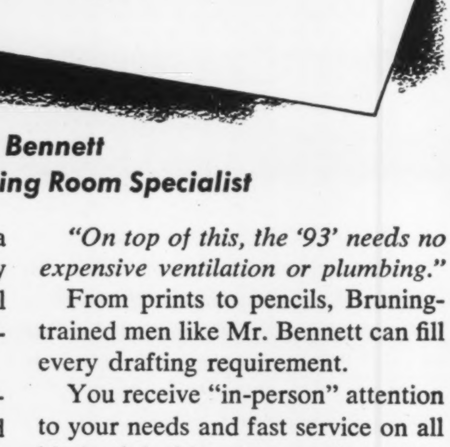

MODEL 93 COPYFLEX

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Design Abstracts

(*Continued from page* 373)

either be inherent in the part or it may result from metallurgical processes. Thus the role of plastic flow may be limited in this case to the propagation of the crack; or it may not even be necessary if the crack propagates by another mechanism.

Metallurgical Effects: During the thermal stress cycle, and between thermal stress cycles, the material is subjected to a complicated stress and temperature history that may cause metallurgical changes in the microstructure. Mention will be made of some of the metallurgical processes that can occur.

AGING: Probably the most important action that takes place during and in between thermal stress tests is that of aging. Most high-temperature alloys in their use conditions are not in metallurgical equilibrium. In fact, it is because of their metastable condition that many alloys gain good high-temperature properties. If the material is maintained at high temperature, the tendency is toward rearrangement of the microstructure in the general direction of seeking equilibrium. Thus, constituents that are in solid solution frequently tend to precipitate, and in so doing, they may drastically change the properties of the material.

CORROSION: Another process that may reduce thermal stress resistance is chemical attack, known otherwise as corrosion, oxidation, and so forth. The surface of the material is usually in contact with oxygen or other gas capable of chemical reaction with the material. At the high temperatures involved in thermal stress testing, oxidation or other scales may form which are weak and brittle. Thermal shock testing then becomes a test, not of the original material, but of the resulting surface layer. Discontinuities formed at the surface layer either by cracking of the surface or by the disintegration of a corroded product act as a source of stress concentration that induces and propagates further

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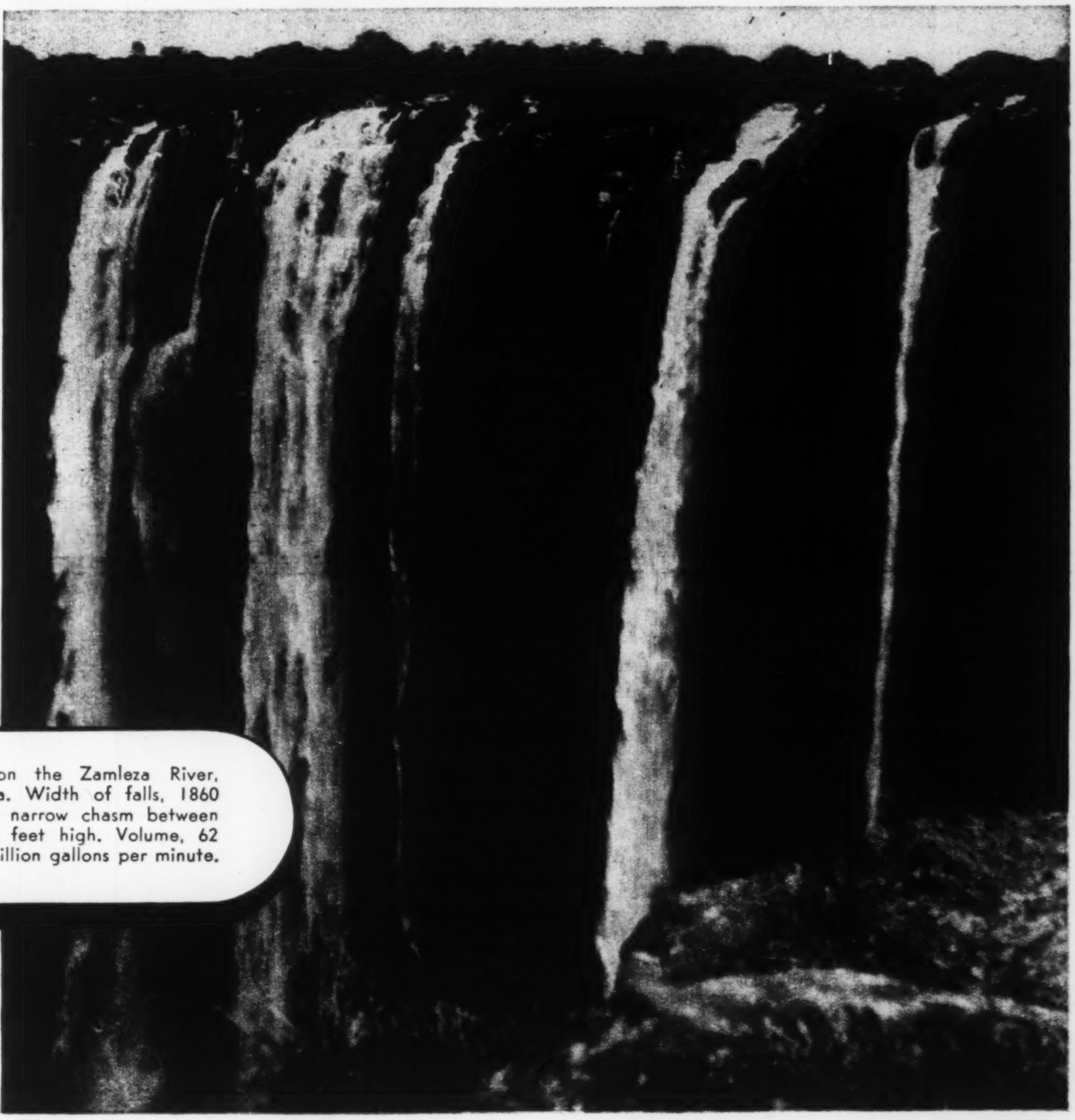

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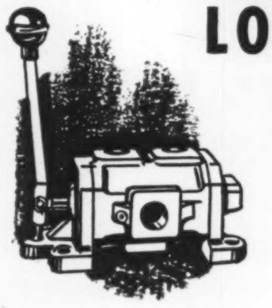

Illustrated, Model 4095—4-way, 2-position valve for directing pressure alternately to ends of double-acting hydraulic cylinder.

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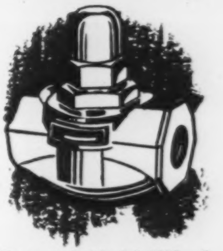

Illustrated, Model 8015 adjustable speed control valve. Install between operating valve and one end of cylinder to meter flow of oil in one direction with free flow on return.

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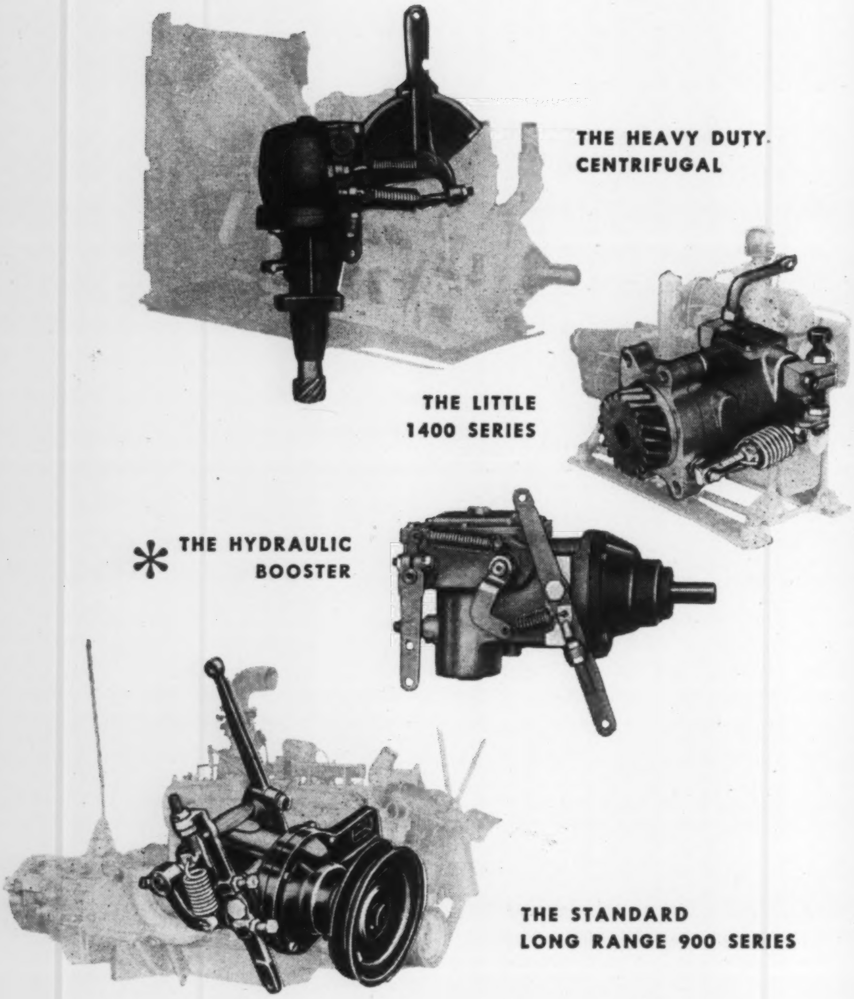
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cracks within the body of the material.

Effect of Stress Concentration: In brittle materials the stress at a point of stress concentration is usually the governing stress leading toward failure. Hence, stress concentrations are certainly of the greatest importance in the thermal shock of brittle materials. In ductile materials, stress concentrations are not of the utmost importance for single application of loading, but become as important as in brittle materials as the load is applied cyclically. Thermal shock in ductile materials generally occurs only after several applications of the shock loading. Hence, stress concentration is of great importance even in ductile materials. This is especially true if the metallurgy of the material is severely affected by localized plastic flow.

Effects of Constraints: Thermal stresses result from constraints that prevent free expansion of the various sections of the part under consideration. While in many cases the constraint is inherent in the physical continuity of the part, it frequently is possible to incorporate some measure of relief by proper design.

Size Effects: Large size is really nothing more than the addition of constraint, since in a body of large size the portion undergoing rapid temperature change is generally prevented from expansion or contraction by a massive section which does not perceive the imposed temperature change for an appreciable period of time.

Effect of Initial Surface Stress: In some cases it is possible to introduce initial stresses that counteract the effect of thermal stress and thereby improve thermal shock resistance. The use of shot peening, for example, in order to introduce compressive surface stresses has been amply demonstrated for the case of mechanical fatigue at room temperature. The same idea can be applied to parts operating at high temperature pro-

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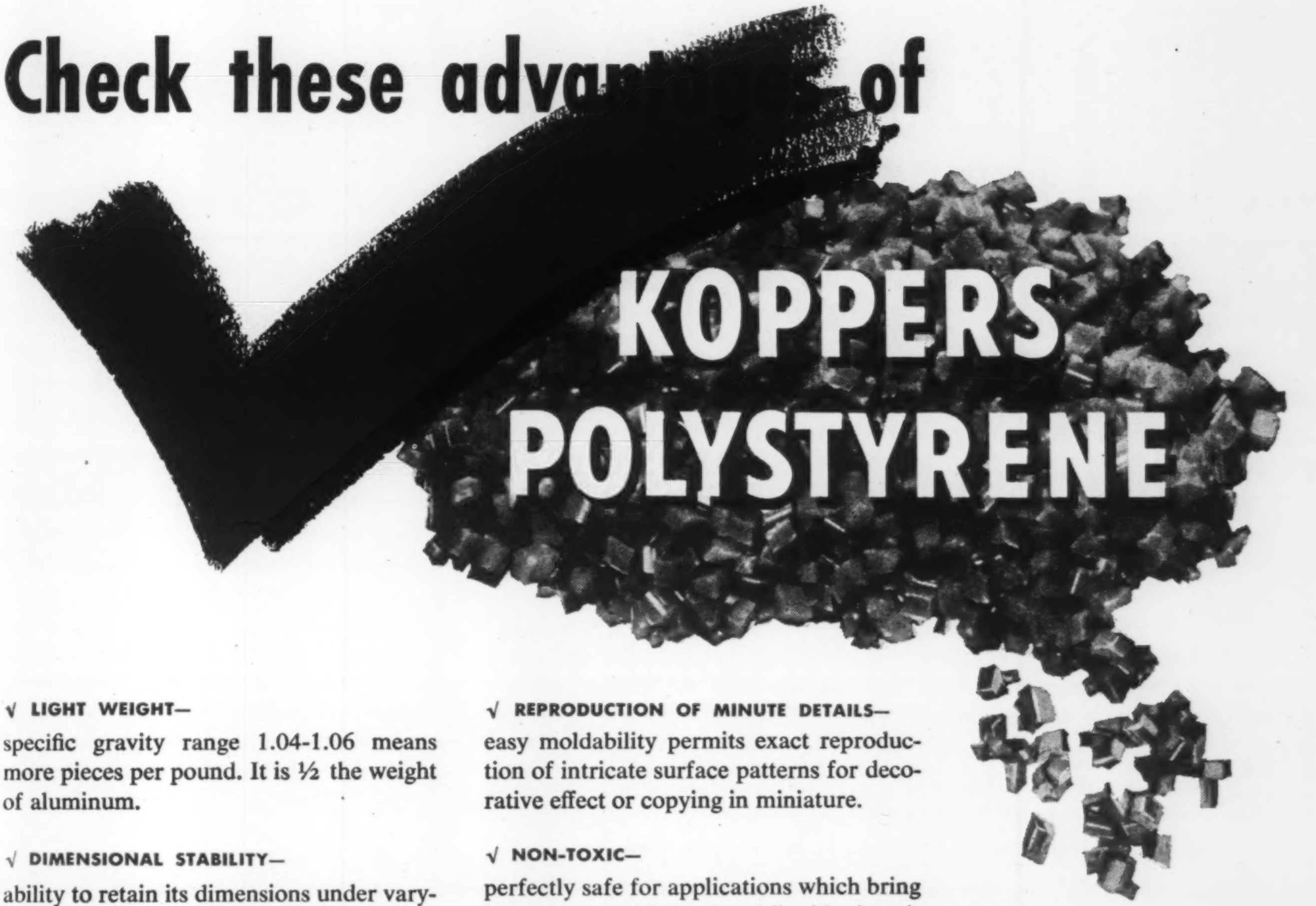

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MC-305	High Impact, Easy Flow
MC-309	High Impact, Highest Heat Distortion Temperature
MC-401	Medium Impact, Improved Heat Distortion Temperature
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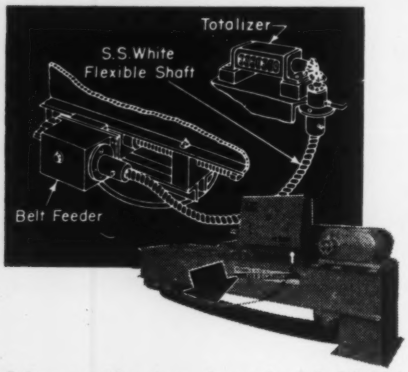

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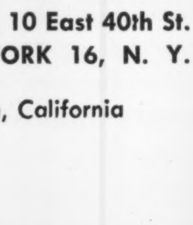

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vided that the temperature is not so high as to anneal the induced stresses. In some cases the surface stresses should be tensile, in others compressive.

Effect of Surface Coatings: In addition to providing means for inducing suitable surface stresses, surface coatings have at least two other beneficial effects in relation to thermal shock—protection from deleterious atmosphere and thermal insulation.

Effect of Coefficient of Expansion: In brittle materials thermal shock resistance is inversely proportional to coefficient of expansion in all ranges of the nondimensional heat-transfer index. Hence, any reduction that can be made in expansion coefficient will effect a proportional increase in thermal shock resistance. Even in ductile materials, the coefficient of expansion is of major importance. Obviously, in the extreme, if the coefficient of expansion is zero there will be no thermal stress. Materials of low coefficient involve low thermal strain and stress, and therefore should, everything else being equal, be superior in thermal shock resistance to materials of high coefficient.

For brittle materials, considerable use has been made of the concept of reducing coefficient of expansion to gain in thermal shock resistance. Pyrex, a silica glass, owes its outstanding thermal shock resistance to its very low coefficient of expansion. Unfortunately, it is poor in creep resistance and therefore does not lend itself especially well to applications involving prolonged stress at high temperature.

Effect of Elastic Modulus: In the case of brittle materials, thermal shock resistance is inversely proportional to elastic modulus. Hence, low elastic modulus is an asset to good thermal shock resistance. Graphite, for example, owes its good thermal shock resistance, at least in part, to its very low elastic modulus, approximately 0.7 × 10^6 pounds per square inch. While the major

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Oil Leak Causes $100,000 Blaze in Local Plant

Fire caused by an oil leak destroyed most of the Holmesburg Manufacturing Company's plant last night in a blaze causing damage estimat $100,000. Flam

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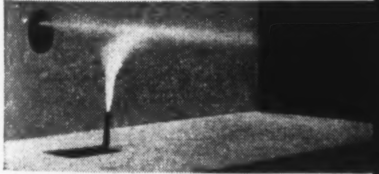

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Perfected after more than five years of research and field testing, Houghto-Safe offers protection to both men and machines. This new hydraulic fluid . . . rated "acceptable from the fire hazard standpoint" by Factory Mutual . . . now proves that fire-resistant qualities *can be obtained without loss in operating efficiency!* In plants performing die casting, welding, hot press forging and other hydraulic operations — especially near open flames or extreme heat — Houghto-Safe is the long-awaited answer. Here are 7 good reasons why it's really safe . . .

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2. **Prevents Corrosion**—The new formula contains inhibitors developed by Houghton to prevent corrosion and rust in any hydraulic system.
3. **It is Non-Toxic**—Safe for workers to handle—and it bears no unpleasant odor.
4. **Fortified Lubricity Saves Equipment**—Reinforced for high film strength by a chemical additive that gives metal parts greater protection for longer periods.
5. **Oxidation Stability Adds Extra Life**—Its exceptional resistance to oxidation assures longer service life—proved by over 5500 hours of testing in equipment in actual use.
6. **High Viscosity Index Reduces Wear**—New Houghto-Safe has a viscosity index of 150, showing its stability through widely fluctuating temperatures, and providing safe operation at all normal temperatures. It won't freeze—pumps easily at zero without preheating.
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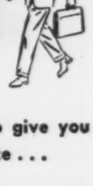

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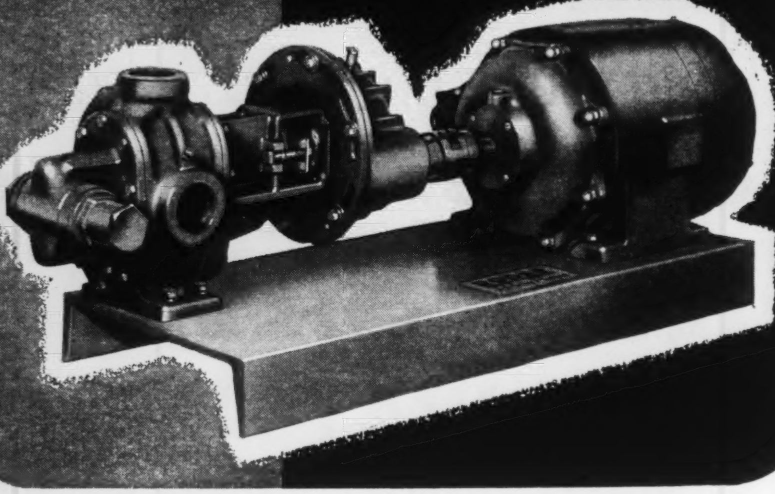
PUMP



If you have a job open for a pump, then by all means consider the Roper Series 3600 as the heart of your fuel transfer system. Designed to handle thin or thick liquids quickly and safely, these pumps offer you the many advantages of the rotary gear principle, plus a most important benefit — Roper *dependability.* There is a size for your needs, as models are available from 40 to 300 G.P.M. sizes — pressures to 60 P.S.I.

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☑ **Compact** . . . requires minimum of installation space.

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☑ **Gear Reduction** . . . totally enclosed and running in oil. Three gear ratios available.

☑ **Anti-Friction** bearings throughout gear reduction.

☑ **Steel Bed Plate** provides rigid foundation for pump and motor.

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☑ **Suction Lift** . . . up to 15 feet at 60 P.S.I.

☑ **Helical Gears** . . . run in axial hydraulic balance. Pump fitted with 4 high-lead bronze bearings; split-type gland.

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attribute of Pyrex glass is its low thermal coefficient of expansion, it should be noted that its outstanding overall characteristic is due also to its relatively low elastic modulus, approximately 8.5 × 10^6 pounds per square inch.

In ductile materials the elastic modulus is probably also important, but not so much as in brittle materials. In any case, thermal shock resistance bears an inverse relation to elastic modulus, all other factors being equal.

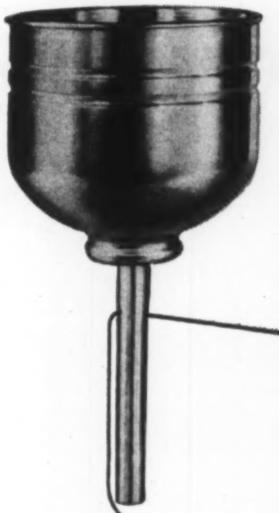
From NACA Technical Note 29933 (July 1953), "Behavior of Materials under Conditions of Thermal Stress."

High-Strength Bolting

NO ONE fastening method can claim to be the best. Each has its own advantages and limitations. However, bolting with high-tensile bolts features three distinct advantages—adaptability, strength, and economy. High-tensile bolts properly installed are fasteners with a permanence equalling the life of the structure itself.

Yet bolted structures offer the greatest simplicity for additions or alterations. Bolts are easily removed and just as easily replaced. There is no need to cut, chip, burn, or use any other destructive method. Just a wrench, either manual or power driven, will do the job and the bolt, once removed, is reusable. Such adaptability puts bolting in a class by itself.

In shape, dimensions, and appearance, the high-tensile bolt is nothing more than a common bolt. It is used in its as-forged condition without any secondary machining operation and is assembled into a standard clearance hole as used for rivets. The only thing that might be different is the underside of the head and the nut bearing face which are semifinished. They are machined to give a truer bearing on the washer than would be the case with a rough bolt and nut. Hardened washers keep the bolt head and nut from imbedding into the softer structural steel. The nut is standard. It has no built-in locking devices; they aren't needed. High-tensile



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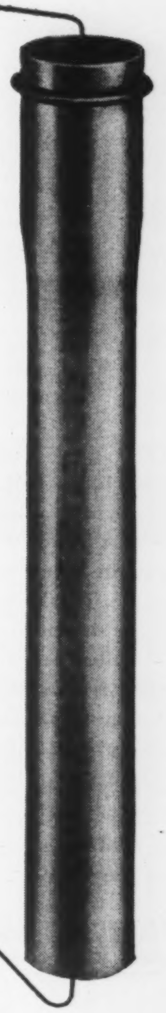
PRODUCED BY THE MAKERS OF ELECTRUNITE — THE ORIGINAL ELECTRIC WELDED BOILER TUBE



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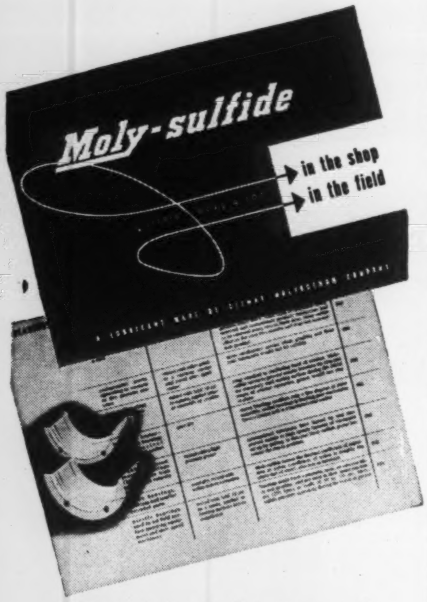

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MOLY

MD-10 MS-6A

bolts, once tightened, don't loosen.

Strength Specifications: The basic principle of the bolted joint is simply this—clamp the members together tightly enough to carry the loads by friction. It takes a high clamping force to do this and this force must be delivered by the bolts. To develop the high bolt load necessary and, more important, maintain it in service, the bolt itself must be strong. It is known that a ¾-inch diameter high-tensile bolt will lift 20 tons, a ⅞-inch bolt can lift 25 tons, and a 1-inch bolt 33 tons.

Forged from medium carbon steel, the high-tensile bolt is heat treated to meet the requirements of ASTM specification A325. These requirements call for a proof load of 85,000 psi for ¾-inch bolts and 78,000 psi for ⅞ and 1-inch bolts, and an ultimate breaking load of 120,000 psi.

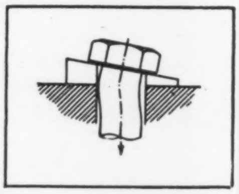

Fig. 1—Standard tensile test wedge loading for determination of ultimate bolt strength

Despite these high strength requirements, the bolt still retains its ductility. In the A325 test of the ultimate strength of the bolt, a 10-degree bevelled washer is placed under the head as shown in *Fig.* 1. Even though subjected to this severe combination of tension and

Table 1—Bolt Tension and Torque Values

Bolt Size (in.)	Bolt Tension* (lb)	Equivalent Torque† (lb-ft)
½	11,500	100
⅝	17,300	180
¾	25,600	320
⅞	32,400	470
1	42,500	710
1⅛	50,800	960
1¼	64,500	1,350

*Minimum required; equal to 90 per cent of specified minimum elastic proof load of bolt.

†Equal to 0.0167 lb-ft per inch bolt diameter per pound tension with non-lubricated bolts and nuts. The values of equivalent torque are experimental approximations. If torque rather than tension is to be measured, the torque-tension ratio shall preferably be determined by the actual conditions of the application.

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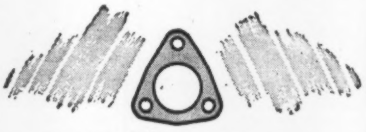

YOUR SUPPLIER SHOULD
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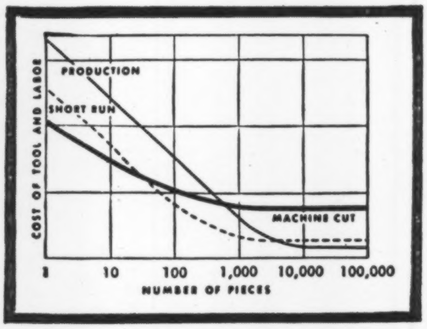

This logarithmic chart shows the effect of these factors on the **specific part** illustrated. From 1 to 65 parts, our own Machine-Cut Method with standard dies is most economical. At 65 parts, the Short-Run Method using economical blanking dies and stock punches is best until, at 7,000 units, the standard Production Method with standard dies is most satisfactory.

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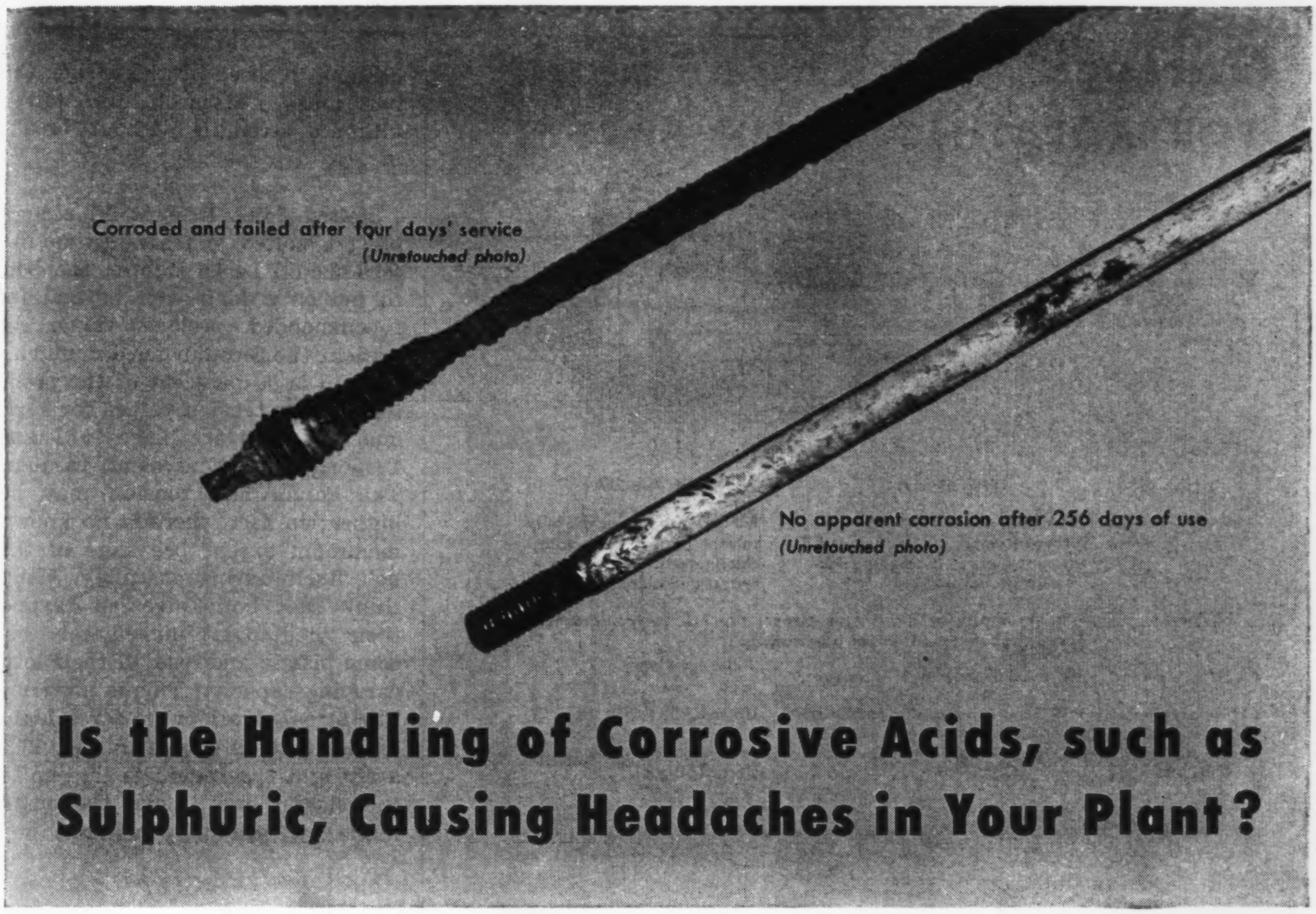
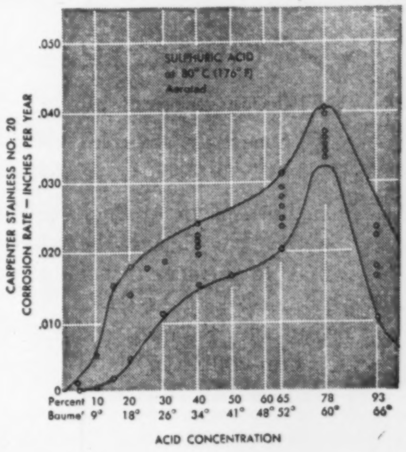

Corroded and failed after four days' service
(Unretouched photo)
No apparent corrosion after 256 days of use
(Unretouched photo)

Is the Handling of Corrosive Acids, such as Sulphuric, Causing Headaches in Your Plant?

Today many plants are enjoying new freedom from corrosion, longer equipment life and fewer shutdowns . . . because of Carpenter Stainless No. 20. Take the job shown above. In this application, ½" rd. rods of Carpenter No. 20 and Stainless Type 316 were installed to handle H_2SO_4 at the rate of about 50 gallons a minute in a full range of solution varying from 0% up to 58% concentration. Temperature: 70° C. (158°F.). After four days the Type 316 rods failed and were replaced with ½" sq. No. 20 rods. After being in service 3,747 hours of a possible 6,144 hours over a period of 256 days, the No. 20 rods showed no apparent corrosion whatsoever. (See unretouched photo above.) Of course, Type 316 is satisfactory for certain dilute solutions of H_2SO_4 and many other corrosive conditions. But with a tough problem like the one described here, it takes No. 20 to do the job.

While the production of Stainless No. 20 is controlled by Government Regulations, you may be able to obtain Government approval of its use, depending on the nature of your job. If not, keep these facts in mind because of their importance in your planning for future products. Meantime, write on your Company letterhead for more details in the No. 20 booklet. Also, get in touch with us for No. 20 test coupons. We'll be glad to work with you. The Carpenter Steel Company, 120 W. Bern St., Reading, Pa.



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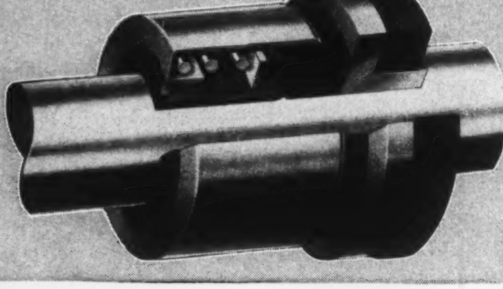
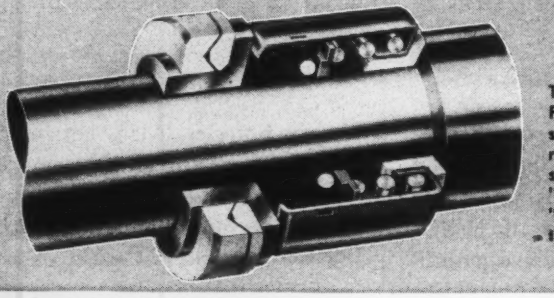
Garlock "Package" Seals
FOR ROTATING PUMP SHAFTS



Type BB-21A—Garlock Package Seal of standard construction with brass shell, brass washer, and Buna-N bellows.

	TYPE BB-21A	TYPE AA-21A
Liquids	For water, oils, alcohol, solvents (except aromatic, chlorinated and ketone types) and other liquids (except strong acids).	For very strong acids, oils, solvents (including aromatic, chlorinated and ketone types) and all other liquids.
Equipment	Rotating shafts of centrifugal pumps, process pumps, chemical pumps, agitators and similar applications.	
Sizes	For shafts from ⅜" to 3" diameters.	
Temperatures	With Buna-N bellows up to 212°; with silicone bellows up to 450° F.	Up to 450° F.
Pressures	Up to 150 p.s.i.	Up to 150 p.s.i.



Type AA-21A—Garlock Package Seal with hat-shaped "Teflon" drive ring, brass or 316 stainless steel shell and washer, "Teflon" 'O' ring, and "Teflon" two-piece vibration ring.

✓ CHECK THESE IMPORTANT FEATURES

☐ Occupy very small space
☐ Completely assembled—ready to install
☐ Proven performance at low cost
☐ Both types are dimensionally interchangeable

In both of these Package Seals, a leakless seal is provided by a positive contact between carefully lapped metal-to-carbon mating surfaces. All metal parts in both types are available in plated-brass, Ni-Resist, stainless steel with malcomized face, Garlock "B" iron, and others.

For complete details, ask your Garlock representative or write us about your sealing problems.

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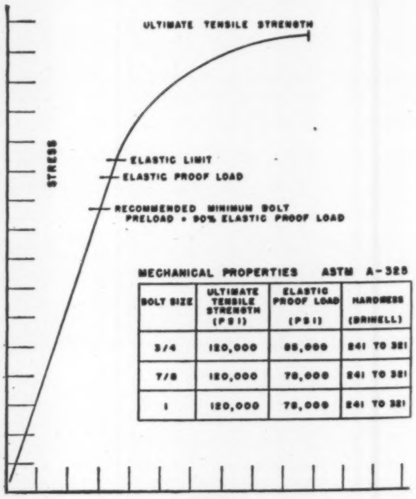
RUBBER EXPANSION JOINTS

bending imposed by the wedge, the bolt must still meet its required ultimate strength without breaking.

Bolted Joint Design: In assembling a bolted joint, the prime object should be to tighten the bolt to induce a load well beyond its recommended preload value. At present the recommended minimum preload is 90 per cent of the proof load. These tension values for various bolt sizes are listed in TABLE 1 along with equivalent torques. The actual bolt tension may be higher; in fact, there is no known maximum except breakage of the bolt itself during assembly. Many think that bolts stressed beyond their yield point immediately become plastic and lose all their load carrying capacity. This is not true. The stress-strain curve for a high-tensile bolt as shown in *Fig.* 2 is a straight true modulus line up to the elastic limit. Then the curve levels off gradually without any sudden or clearly defined yield point, to an ultimate strength that is 70 per cent greater than the minimum preload requirement. These are two important facts—first, there is no sudden yield point, and second, this 70 per cent is a reserve strength which gives the bolt plenty of additional capacity above the minimum requirement. Joints with bolts stressed beyond



MECHANICAL PROPERTIES ASTM A-325

BOLT SIZE	ULTIMATE TENSILE STRENGTH (PSI)	ELASTIC PROOF LOAD (PSI)	HARDNESS (BRINELL)
3/4	120,000	85,000	241 TO 321
7/8	120,000	78,000	241 TO 321
1	120,000	78,000	241 TO 321

Fig. 2 — Typical stress-strain curve for high-tensile strength bolts

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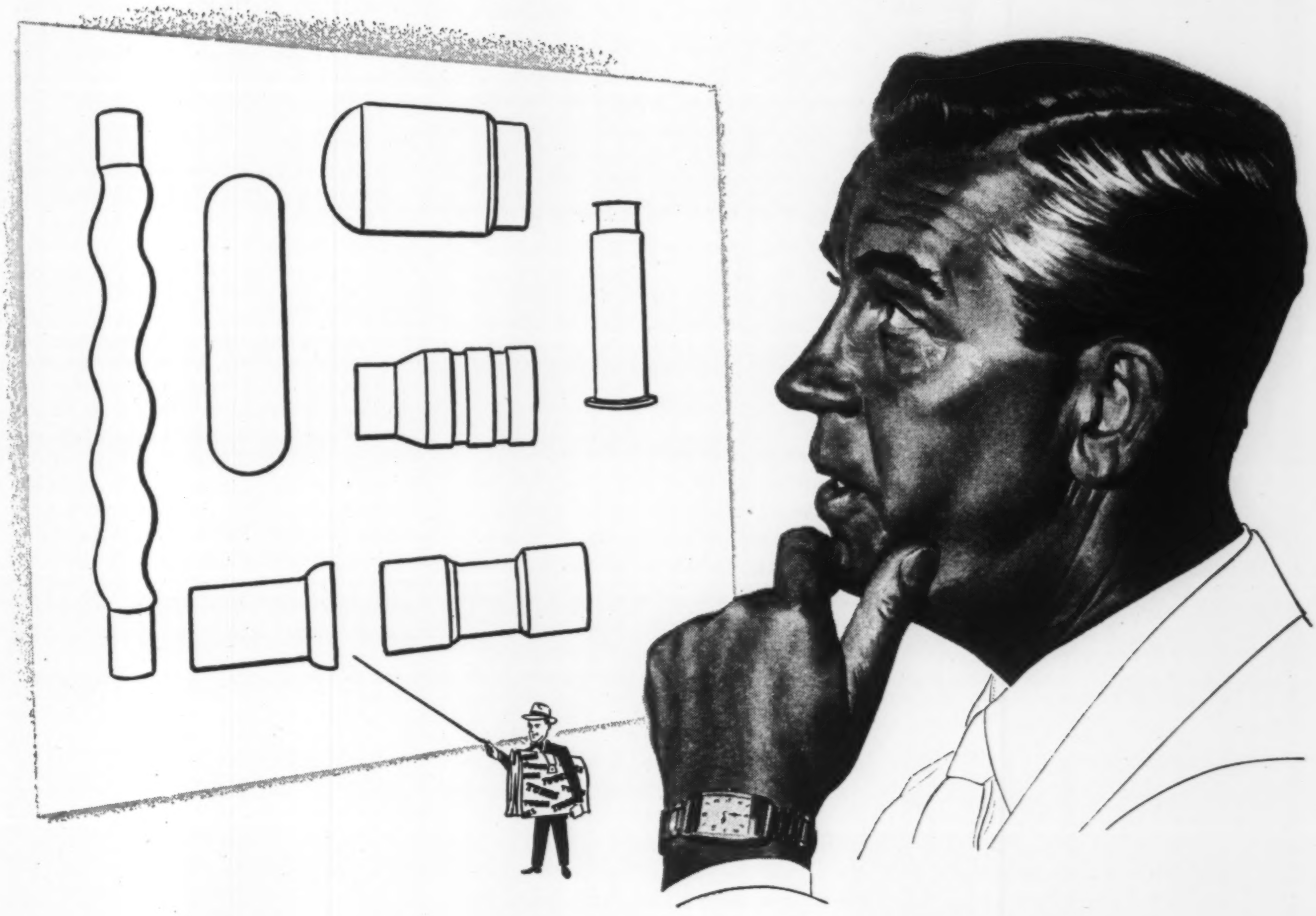

When selecting tubing for forming into any part or product, the fabricator should be certain that the tubing has the optimum combination of formability and structural strength required by the product . . . should also consider the ease with which it can be formed—hot or cold—with his available equipment.

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their yield point will perform equally well as joints with bolts carrying the recommended preload. They will carry just as much load statically as in fatigue and the bolts themselves are not weakened due to overtightening. This has been satisfactorily demonstrated many times.

In designing bolted joints, the present practice is one of substitution—design for riveted construction and then for each rivet use one bolt of the same size. Statistically, the bolted joint is stronger. The reason is quite simple—the higher strength steel of the bolt will carry more load in shear than the same size low-carbon steel rivet. The ratio of their respective shear strengths is better than 1.5 to 1 which means two bolts will safely carry the same shear load as three rivets.

Bearing Stress: With a straight substitution of a bolt for a rivet, the working loads will be carried by friction. If, however, the number of bolts is reduced by one-third to take advantage of their higher shear strength, the load will probably be carried by some combination of friction and shear. This introduces two new problems—bearing and end distance. Bearing stress of the fastener on the connected material should of course be investigated but in all likelihood the dimensions of the joint will not be affected because of three reasons. First, bearing is usually only a consideration in those joints with connected material thinner than one-half the fastener diameter; second, even though the bolts may be in bearing, the larger percentage of the load will still be carried by friction; and third, the present design stresses for bearing are too conservative almost to the point of being unnecessarily restrictive. The latter fact is supported by research results.

End and Edge Distance: End distance is a very important consideration. Present end distances as related to riveted work are now perfectly adequate for fastener shear stresses not exceeding 15,000 psi. However, an increase in the allowable shear stress must be accom-

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WELDED DESIGN ELIMINATES BREAKAGE CUTS COST 78%

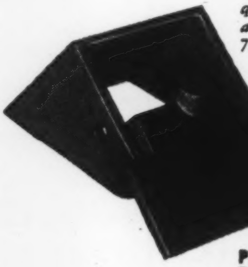
SINCE steel is a ductile material, it withstands shock loads without fracture. As a result, to eliminate shock failures, machine components can be simply changed to welded steel construction. At the same time, manufacture is made simpler, material cost is less, and fewer manhours are needed for production to cut costs an average of 50%.

The Problem

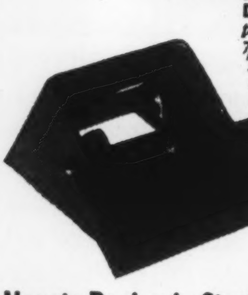
In the examples shown, breakage in the flipper assembly created service problems for this company. Because of limited clearance, it was impossible to increase wall sections.

The Solution

By converting to welded steel construction, the manufacturer was able to eliminate breakage completely, yet cut his cost from $4.50 to $1.00 per unit. The one and one half pounds less metal now needed actually produces a stronger, more rigid assembly than possible before. The entire unit is produced in the shop without waiting for outside sources. With less machining and less cleaning, fewer manhours are required to turn out a more dependable product.



Original Construction — *Cost $4.50, required extra drilling and tapping. Weight 7.5 pounds.*



Present Welded Steel Design — *Saves $3.50 per assembly . . . a 78% reduction in cost. Takes 12 pounds less metal. Needs less machining, less cleaning.*

How to Design in Steel and Cut Costs

Lincoln design specialists throughout the country are equipped to train product designers and production engineers on how to simplify designs for low cost manufacture. Design bulletins are also available by writing on your letterhead to Dept. 1108.

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panied by an increase in the end distance. This prevents the possibility of failure by tearing out at the end of the connection. A safe increase would be 50 per cent over that now recommended for riveted design. End distance is not to be confused with edge distance which needs no change from riveted practice.

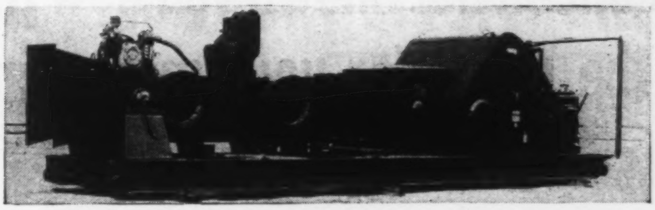
Static Loading: Only by the development of enough friction to carry the working loads will slip of the joint be prevented. Slip in structural joints is something which some engineers feel should be avoided at all costs. However, a realistic appraisal of the relative importance of slip readily shows the over conservatism of this viewpoint. Maximum free slip of any joint is limited to the hole clearance. This can only occur when the holes in the connected members are perfectly matched and the experienced know perfect matching is the exception and not the rule. In fact, in most joints, at least one or more of the bolts will be in initial bearing before any of the service loads come onto the structure.

Dynamic Loading: While in most statically loaded structures, slip is of minor importance, there are certain joints in dynamically loaded structures where prevention of slip may be the prime consideration. For these points special treatment to increase the factor of safety against slip may be necessary. The easiest way is to increase the clamping force on the joint by simply adding more bolts or by using larger bolts.

Tension Loading: Joints loaded in direct tension may be few but joints in combined shear and bending are quite common. If the connection is wholly or partially tension loaded, the bolted joint is superior. At first thought it would seem that an external tension load would add to any tension already in the bolt. This is an apparently obvious fact, but like an optical illusion the seemingly true is usually false. Until such time as the external tensile load exceeds the bolt load, the bolt load will remain

(*Continued on page 394*)

The Filter That Manufacturers Install



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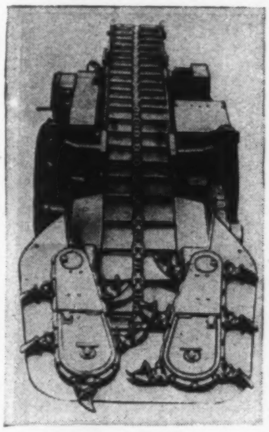
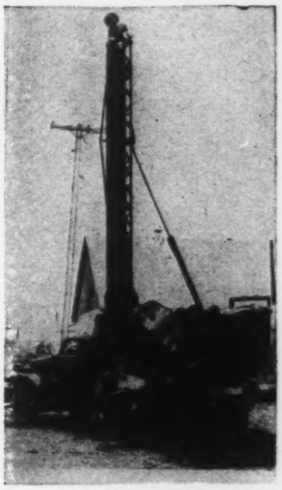
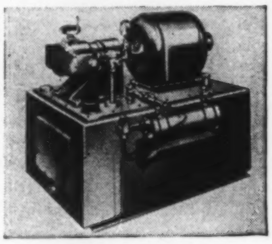


UNDERGROUND
LOADING MACHINE
The Clarkson Mfg., Co.
Nashville, Illinois

SUMP TYPE
(Cutaway)



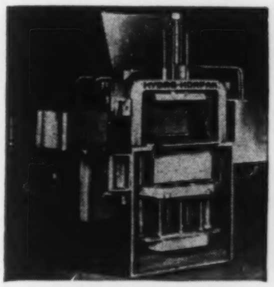
HOLE DIGGER
Hugh D. Williams Mfg. Co.
Dallas, Texas



HYDRAULIC PUMPING UNIT

Dennison Equipment Co.
Columbus, Ohio

LINE TYPE
(Cutaway)



MASONRY BLOCK
MAKING MACHINE
W. E. Dunn Mfg.,
Holland, Mich.

O.E.M. Choice of Over 350 Manufacturers
MARVEL SYNCLINAL FILTERS

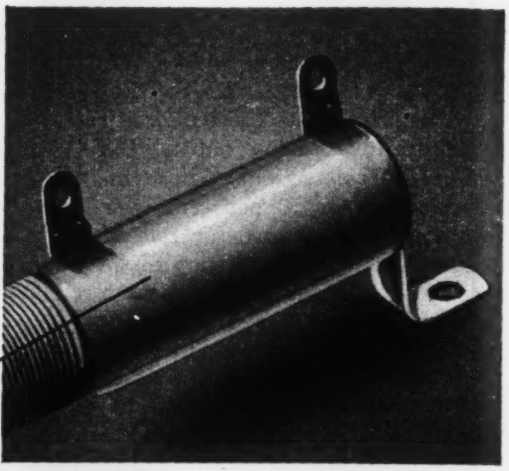
are installed on all types of hydraulic and oil recirculating equipment. Illustrated are machines representative of the many which are protected by Marvel Synclinal Filters. Reasons for this overwhelming preference include: Greater ACTIVE filtering area; Longer operation before cleaning; Simplicity that enables any workman to do the infrequent cleanings quickly and on the spot. Line types operate in any position and may be serviced without disturbing pipe connections. Both sump and line types available in capacities of 5 to 100 g.p.m. and monel mesh sizes from 30 to 200.

MARVEL
ENGINEERING
COMPANY
625 W. Jackson Blvd.
Chicago 6, Ill.

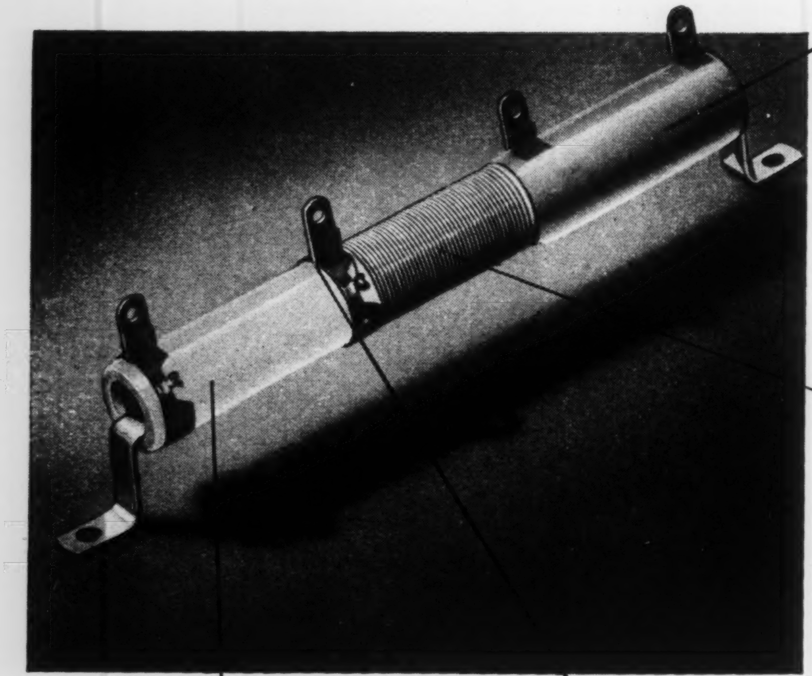
WATER FILTERS
In response to the great demand we have adapted both our sump and line models for use in all water filtering applications. No changes have been made in the basic synclinal design.

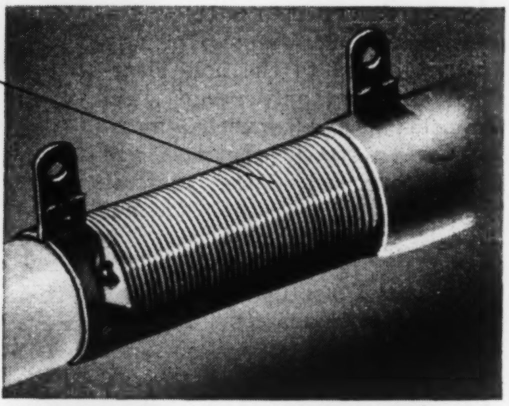
MARVEL ENGINEERING COMPANY MD-10
625 W. Jackson Blvd., Chicago 6, Ill.
Without obligation, please send me your catalog #106, containing complete engineering data on Marvel Synclinal Filters.
Name ....
Company ....
Address ....
City .... Zone .... State ....

This check list shows you how to get the most for your money in terms of resistor performance

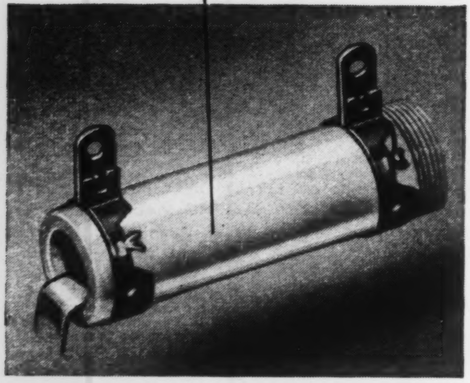


COATING. Vitrohm enamel coating of all Ward Leonard resistors provides a complete hermetic seal highly resistant to shock, high humidity, extreme temperatures, acids, alkalies, and electrolysis. Unlike most resistor manufacturers, we manufacture our own vitreous enamel.

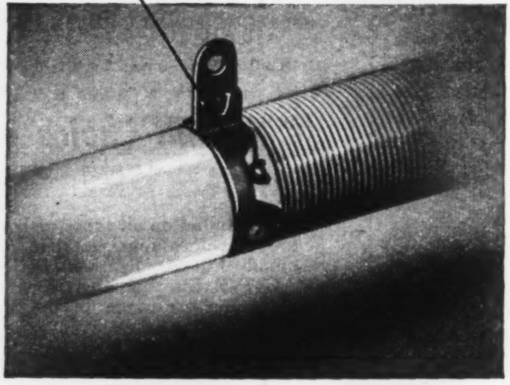




RESISTANCE WIRE. The resistance wire is drawn to Ward Leonard's own specifications for each particular resistor type. It is capable of withstanding heavy overloads, has a uniformly low coefficient of resistivity. Many of the "bargain" resistors are wound with resistance wire of ordinary grade.



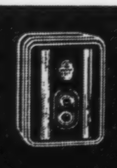
RESISTOR CORE. Ward Leonard's own manufactured cores upon which the resistance elements are wound consist of a perfectly cylindrical ceramic body of high density, low porosity, and high dielectric strength, with a thermal coefficient of expansion correlated to the expansion of the enamel.



TERMINALS. In Ward Leonard resistors, special alloy terminals insure proper expansion and adherence to the enamel, are designed to provide strong anchorage. Every wire-to-terminal junction is joined mechanically first, then specially silver-brazed for lasting contact.

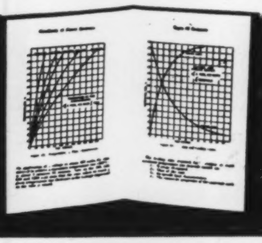
RHEOSTATS

RELAYS



MOTOR CONTROLS

CHROMASTER



Ward Leonard's complete engineering textbook, "Handbook of Power Resistors," $3. per copy.

"O.K. But what's your price for performance?"

Here's a purchasing agent buying resistors on a price basis. But doing it the *right* way.

Some day we may even be able to quote resistor prices in terms of performance—so many cents per thousand hours of trouble-free operation. Then we'll be able to tell you exactly how much *less* Ward Leonard resistors really cost than the so-called "bargain" resistors now on the market.

But until then, remember, it's *performance* you pay for when you're buying resistors. There's a lot more than just a few cents difference in the performance you'll get from the two resistors above.

The one made by Ward Leonard will perform at its rated value for the life of the product it goes into. There's a chance the so-called "bargain" resistor will too. But you can't afford to take *any* chances on your product's failure—even once out of a hundred times. Not when you consider the actual cost of such failure, figured in terms of returned merchandise, replacement cost, customer and dealer dissatisfaction.

That's why, even on a price basis, the accuracy, dependability and uniformity of Ward Leonard resistors make them far better buys than any of the questionable bargains you'll find on the market. Send for *new* Resistor Catalog No. 15. Ward Leonard Electric Co., 58 South Street, Mount Vernon, N. Y.

3•18

WARD LEONARD

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ELECTRIC COMPANY
MOUNT VERNON, NEW YORK
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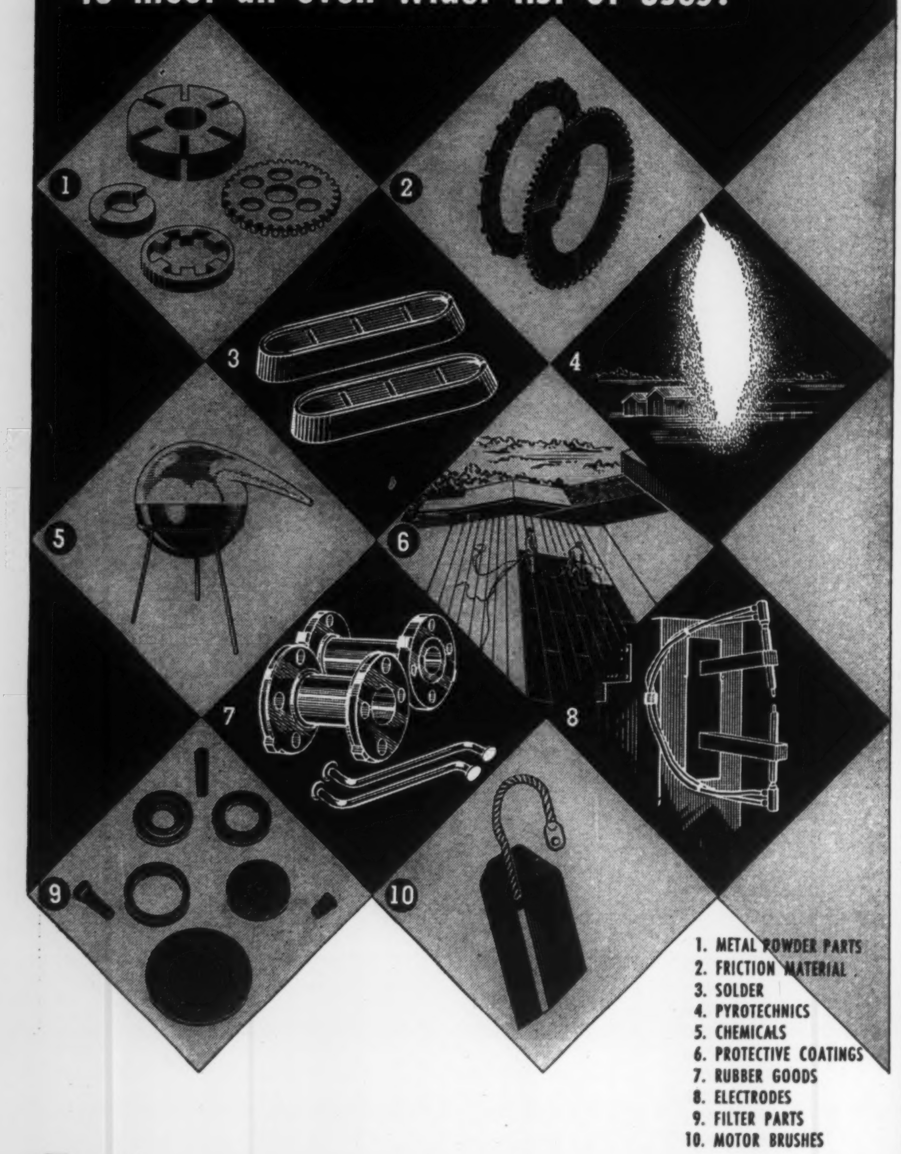
Here's the widest range of Metal Powders to meet an even wider list of uses!



At MD, a user finds a complete line of Metal Powders—to meet an even wider group of varied and greatly diversified uses, some of which are illustrated here.

Here, in addition, the Metal Powder user finds the extensive MD laboratories and their constant research dating all the way from 1916 into *tomorrow!* Here are the plants devoted to the manufacture of Metal Powders in greater quantity than anywhere else.

That's why it pays to take your Powder Metallurgy problem direct to Metal Powder Headquarters. Save time as well as costs—one call to MD does it all!

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2342

ORIGINATOR AND OLDEST PRODUCER OF ALUMINUM PASTE

Design Abstracts

(*Continued from page* 391)

unchanged. Change in stress must be accompanied by change in strain which means that the load in a bolt will change only if the bolt length is changed. Until an external load exceeds the bolt preload, the bolt preload remains constant. Of course this is only true within the limits of the relative rigidities of the bolted material and the bolt itself but this ratio is high enough that the bolt load stays virtually constant. This peculiar ability of bolted joints to withstand tension loads should direct the engineer and the designer to investigate the use of high-tensile bolts in semirigid connections.

Fatigue Strength: The bolted joint is stronger in fatigue—a type of failure which occurs when a material is subjected to a varying stress through a number of cycles. In structural work, for example, fatigue strength is arbitrarily defined as the greatest stress to which a material or joint can be subjected two million times before failure.

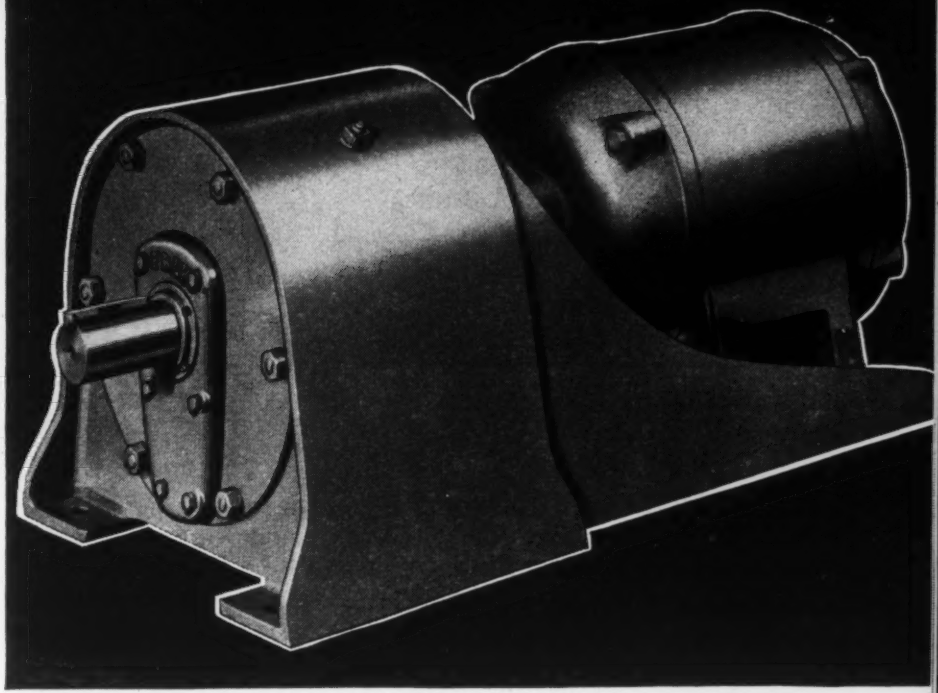
The fatigue strength of a bolted joint must be evaluated two ways—fatigue of the bolt and fatigue of the bolted material. The properly tightened bolt will not fail in fatigue. As already explained, the initial bolt tension will stay relatively constant until the external tension load on the joint exceeds the bolt load. In no carefully designed connection of any type would the designer permit the calculated service load to be greater than the bolt preload. Thus, it is safe to say that the bolt will experience no appreciable stress variation. Without stress variation, there can be no failure by fatigue. Therefore, regardless of the number of load cycles on the joint, the bolt itself is immune to fatigue.

This fact may be argued by a stress analyst who may envision a bolt failing if it is tightened to an extreme level. Here even the smallest stress change should in time cause failure. Such is not the case, because a bolt may be broken by tightening but it can't be tightened to this extreme level. This is worth explaining. In tightening a bolt there is a combined stress compounded of axial tension due to

Incorporate the All-

ALL-STEEL FALK

as your standard!



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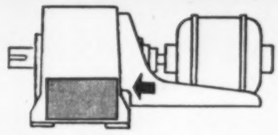
The *all-steel,* All-Motor type FALK Motoreducer assembly can easily be modified to use overload protective coupling, brake-wheel coupling, multispeed transmission or hydraulic fluid drive. Motors with variable speed drive arrangement can be substituted for standard motor.

The All-Motor type FALK Motoreducer . . . the only complete and compact motorized reducer with a separately mounted, resilient Steelflex coupling-connected motor . . . enables the user to replace motors from his spare stock or other convenient source as required, *in minutes*—on the job!

Any make, speed, or type of standard foot-mounted motor within the unit's rating may be used (or interchanged) without modification of gear unit. Ratio of unit can be changed without modifying the motor. Ease of motor replacement and ratio change reduce over-all cost of any equipment-remodeling desired by the customer. Write for Bulletin 3104.



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Positive Lubrication. Large sump capacity . . . oil-tight construction assures clean lubricant . . . direct dip of revolving elements provides positive lubrication at all speeds.

Wide Speed Range. Selective ratio combinations provide output speeds from 1.5 rpm to 1430 rpm with stock gears.

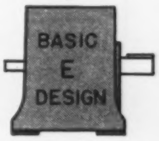
Streamlined inside and outside. Smooth, clean surfaces; machine welded construction conforms to NEMA motor frames.

Sealed Housings. Dual closures and one-way vents keep oil *in,* dust and moisture *out.* Units are splash-proof, leakproof, dustproof.

Precision Gearing. Heat treated alloy steel, precision cut and shaved helical gearing throughout . . . quiet-operating crown shaved pinions . . . taper bored gears for easy ratio changes.

All-steel Housings. Unbreakable, strong, rigid. Generous overhung load capacities provided by wide bearing spans, large shafts and bearings.

• • • • •



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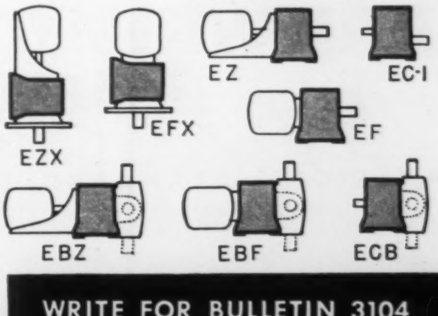
The basic E design permits maximum use of standardized parts . . . closer control over materials, processing, inspection and assembly . . . resulting in faster delivery from interchangeable stocked assemblies.



FALK

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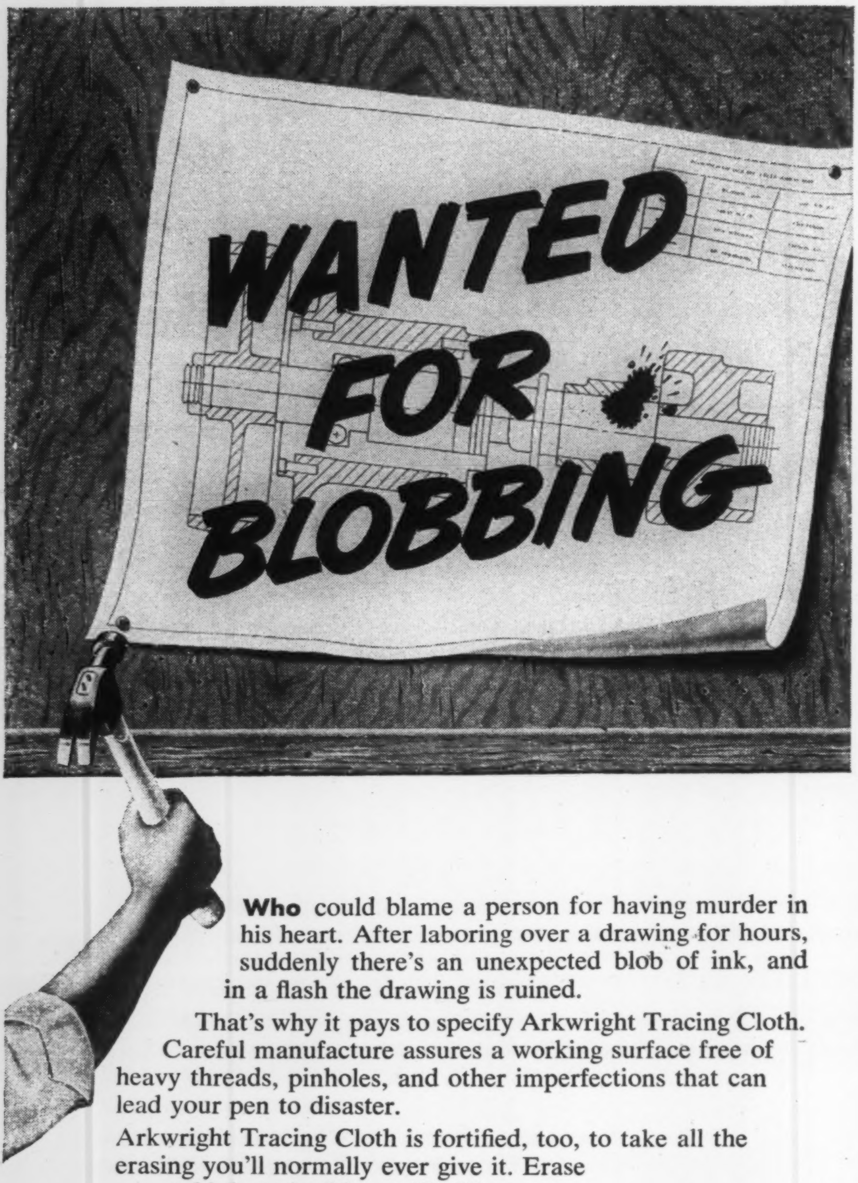
WRITE FOR BULLETIN 3104



Who could blame a person for having murder in his heart. After laboring over a drawing for hours, suddenly there's an unexpected blob of ink, and in a flash the drawing is ruined.

That's why it pays to specify Arkwright Tracing Cloth.

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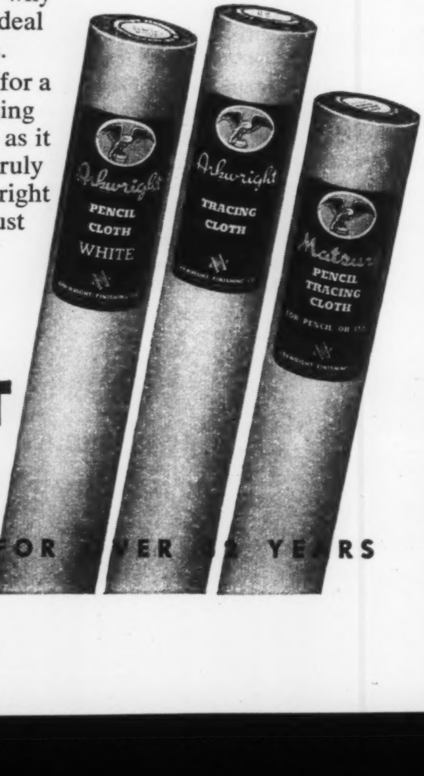
Want to be convinced? Write for a free sample. Arkwright Tracing Cloth will convince you, just as it has thousands of others, it's truly "America's Standard". Arkwright Finishing Co., Industrial Trust Bldg., Providence, R. I.



ARKWRIGHT

Tracing Cloths

AMERICA'S STANDARD FOR OVER YEARS

clamping and torsion due to frictional drag on the threads. The bolt may break during tightening due to this combined stress but at the time of failure the tensile component is only about 80 per cent of the ultimate strength of the bolt. If the bolt is tightened just to the point of failure and the wrench removed, the torsional component quickly disappears, leaving only the axial tensile stress. Thus, when the service loads come onto the joint, some 20 per cent of the bolt strength is still available.

Failure of Connected Members: The second criterion of joint fatigue is failure of the connected members. High tensile bolting very definitely increases the fatigue strength of the member; in fact, this increase is so great that it becomes apparent that failure by fatigue need no longer be a major consideration in the design of those members subjected to stress reversal. Fatigue strength of bolted joints for failure at two million cycles will be in excess of 20,000 psi main member stress.

Usually failure in the connected member will occur through the gross section and not through the net section as would normally be expected. This peculiarity is explained by referring to *Fig.* 3. It is well known that an open hole in a plate acts as a "stress raiser." If the plate is loaded with a loose pin, the bearing of the pin against the plate greatly increases the stress near the hole. If the pin happens to be in single shear, the stress condition is further aggravated because the pin tilts, bringing the load onto one edge of the hole instead of being distributed across the plate thickness. Replacing this

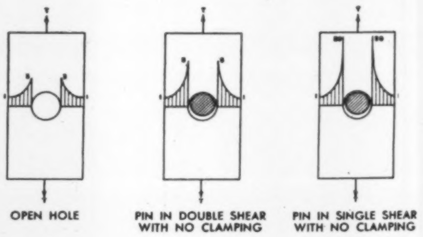
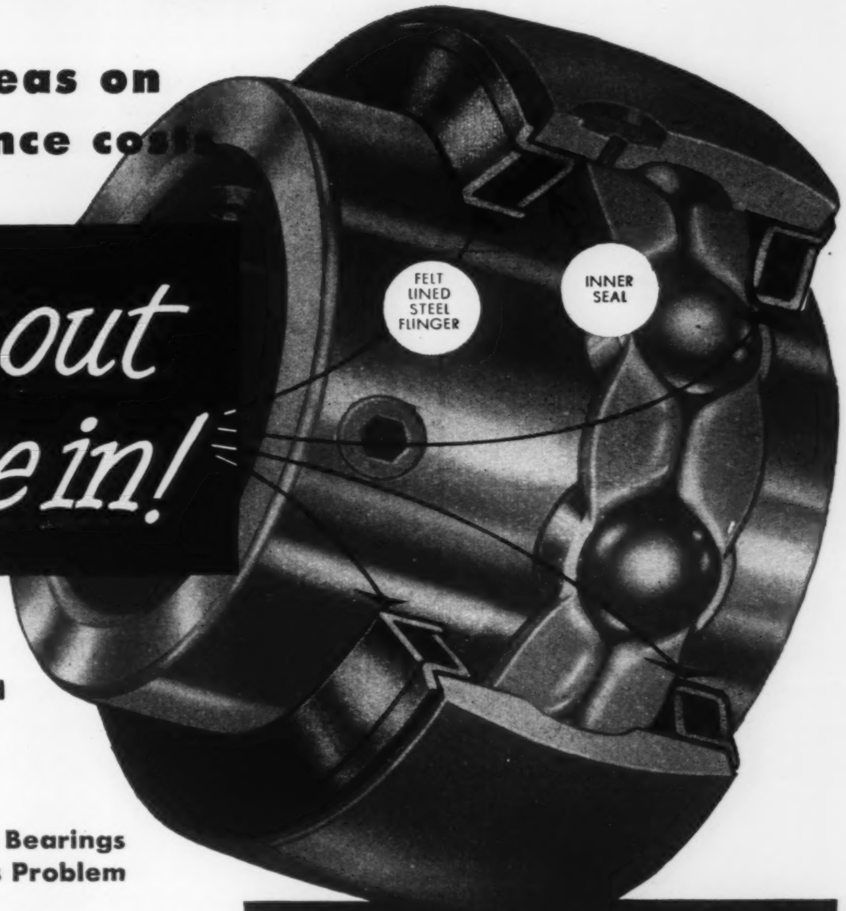

OPEN HOLE
PIN IN DOUBLE SHEAR WITH NO CLAMPING
PIN IN SINGLE SHEAR WITH NO CLAMPING

Fig. 3—Strain concentration around hole in tension joint

THIS SUPER *Seal* (EXCLUSIVE IN SEALMASTER BEARINGS)

obsoletes old ideas on bearing maintenance costs

IT KEEPS dirt out AND grease in!



When dirt gets into bearings or grease leaks out, you've got trouble . . . high maintenance and replacement costs and all-too-frequent disassembly and downtime for machines.

Permanently Sealed SEALMASTER Bearings Were Developed to Lick This Problem

HERE'S WHY: In SEALMASTER Bearings, grooved, steel inner seals—permanently mounted on the outer race ring, one on each side, form the grease chamber.

Two annular felt-lined flingers rotating with the inner race ring and within the grooves of the inner seals, form the outer seals. The centrifugal action of these flingers effectively seals out all dirt. The bottom flanges of these rotating flingers, passing under and slightly beyond the inner seals, create a vortex action in the grease chamber. This breaks up the grease flow and retains just the right amount of grease to lubricate.

Whether your problem is dirt or simply making sure the bearings in the machines you make or use will give maximum service, SEALMASTER Bearings can help *you.* They are first class assurance of low maintenance costs and long bearing life! Write for Bulletin No. 845.

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Flange Unit

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FACTORY REPRESENTATIVES AND DEALERS IN ALL PRINCIPAL CITIES

FASCO makes all turns right—

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Fasco Industries, Inc.
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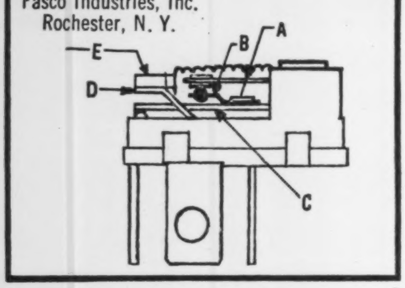

The Fasco Flasher is the switching unit which blinks the front and rear signal light, and a dash pilot light, on modern automobiles to indicate when a turn is about to be made; a big factor in safety and peace of mind on the highways. Fasco flashers are installed as original equipment in many leading makes of cars and trucks.

Heart of the Fasco flasher is a Chace Thermostatic bimetal element which serves a dual purpose—making and breaking the signal light circuit and also protecting the wiring from short circuits and overloads.

In the illustration, the slotted element (A) closes the signal circuit contacts at (B), magnetically energizing frame (E) which pulls up armature (C) against pilot contact (D), lighting the dash pilot light and adding to the upward pressure on blade (A). Signal lamp current flowing through blade (A) causes it to heat and bend upward, breaking the lamp circuit and allowing (B) and (C) to fall and break the pilot light circuit. As (A) cools and touches (B) again, the cycle repeats.

Chace Thermostatic Bimetal is precision manufactured in 29 types, in strips, coils, random long lengths and welded or brazed sub-assemblies. Before proceeding with the design of your new actuating device, consult our application engineers, recognized authorities on temperature responsive devices—or write today for our 32-page booklet "Successful Applications of Chace Thermostatic Bimetal," containing condensed engineering data.

W. M. CHACE CO.
Thermostatic Bimetal
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IT BENDS WITH THE HEAT

pin with a properly tightened high tensile bolt does two things. First, the load is carried by friction; thus bearing is eliminated. Second, the high clamping force exerted by the tightened bolt provides an initial compressive stress in the material around the hole which largely counteracts development of the higher tensile stress concentration such as exists adjacent to the open hole. The combination of these two effects apparently is sufficient to protect the net section through the hole to the degree that if failure does occur it will be through the gross area.

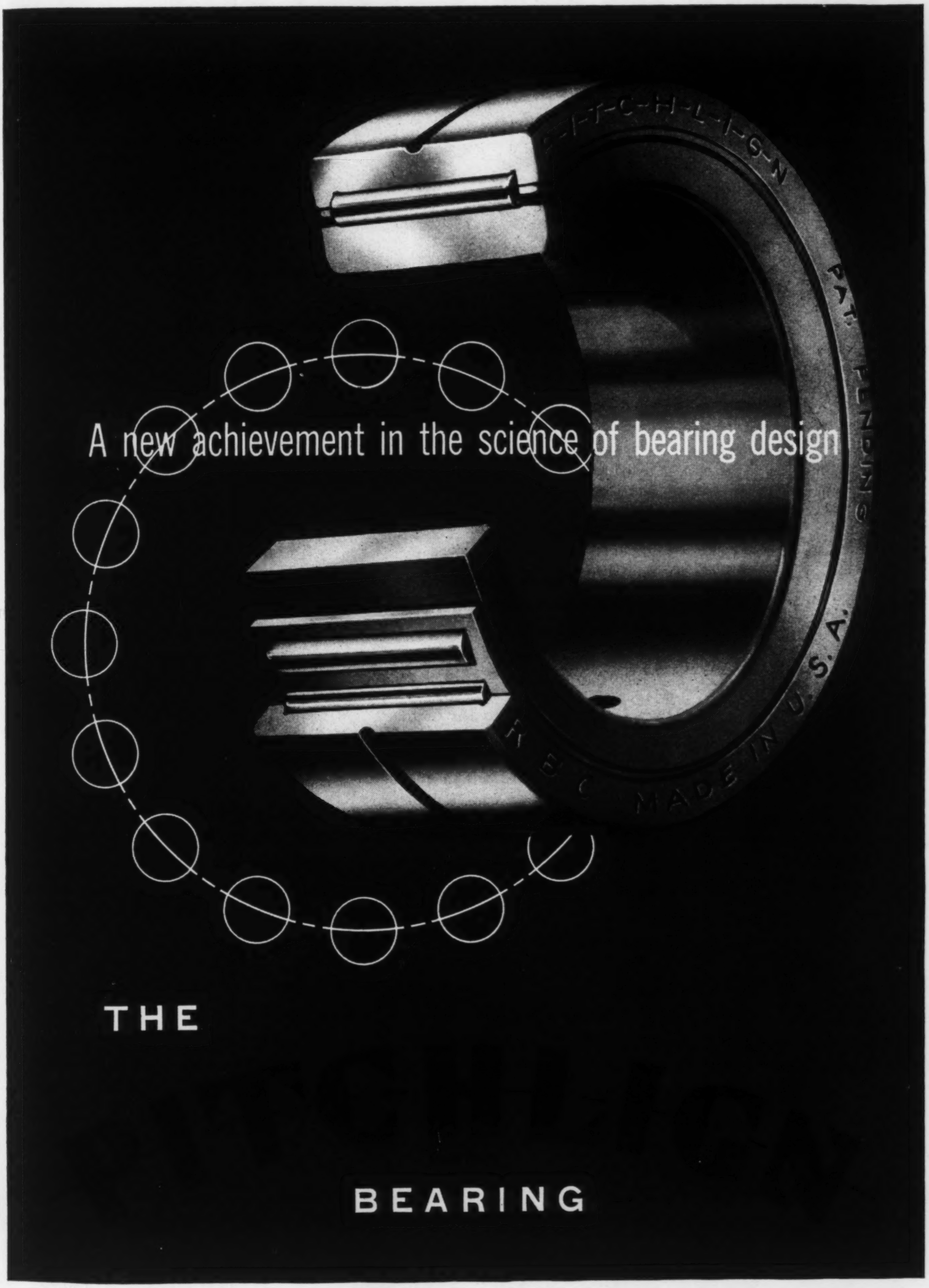
Present design practice requires that those members and their connections which are cyclically loaded be increased in size to offset failure by fatigue. For instance two recognized codes include the requirement that members subject to reversal of stress shall be proportioned as follows:

> The maximum stresses in both tension and compression are determined and each is increased by 50 per cent of the smaller stress. The member is then designed to resist both of the increased stresses. The connection is proportioned for the sum of the two maximum stresses before increase.

Economically, high-tensile bolted joints are now the cheapest type of joint per unit of strength. Further economy is assured. Revision of design codes to permit full use of the bolt's superior strength characteristics will, of course, pave the way for major cost reductions. Permission to paint joint surfaces will further cut the overall cost. Recent research results indicate the possibility of changing present field assembly and inspection practices. While not overly strict now, any change will again be reflected in the cost.

*From an article of the same title appearing in Fasteners (*Vol. 9, No. 1*) a publication of the Industrial Fasteners Institute Inc.*

In the abstract entitled "Adhesives and Sealers" which appeared in the August issue of MACHINE DESIGN, the Thiokol Corporation should be credited as the source for *Figs.* 1, 2 and 3. This reference was inadvertently omitted.


A new achievement in the science of bearing design
I-T-C-H-L-I-G-N
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RBC MADE IN U.S.A.
THE
BEARING

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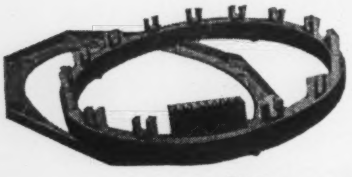

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Formed steel parts designed more economically as stampings withstand extreme heat changes.

Railroad Mechanism Cover
Steel formed in dies requires no further processing—flanges uniform, corners solid, openings flanged.

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Continuous hole of varying diameter—a technique in which we specialize.

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Gear blanks designed to reduce set-up and production costs.

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Meetings

AND EXPOSITIONS

Oct. 19-23—
American Society for Metals. National metal exposition and congress to be held at the Public Auditorium, Cleveland, O. W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, O., is national secretary.

Oct. 23-24—
National Noise Abatement Symposium. Fourth annual symposium to be held at the Armour Research Foundation of Illinois Institute of Technology. George L. Bonvallet, Illinois Institute of Technology, Technology Center, Chicago 16, Ill., is chairman.

Oct. 25-28—
American Gear Manufacturers Association. Semiannual meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. John C. Sears, 302 Empire Bldg., Pittsburgh 22, Pa., is executive secretary.

Oct. 28-30—
American Society of Body Engineers. Eighth annual technical convention to be held at the Rackham Memorial Bldg., Detroit, Mich. Additional information may be obtained from society headquarters, 100 Farnsworth Ave., Detroit 2, Mich.

Oct. 29-30—
Society of Automotive Engineers. International production meeting to be held at the Royal York Hotel, Toronto, Ontario. John A. C. Warner, 29 West 39th St., New York 18, N. Y., is secretary.

Nov. 2-6—
Society of Automotive Engineers. National Transportation (Nov. 2-4), Diesel Engine (Nov. 3-4) and Fuels and Lubricants (Nov. 4-6) meetings to be held jointly at the Conrad Hilton Hotel, Chicago, Ill. Additional informa-

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For maximum load-carrying ability and longer trouble-free life, install the chain with pre-tested strength.

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Resiliency that permits constant spring-back to original shape . . . and good absorptive characteristics . . . are just two of the many properties you can get in Felt made by Felters.

If you have a problem that could be solved by a soft, porous material, or by a hard, dense material — your answer could well be a Felt made by Felters.

The "Felters Design Book" describes several usual and unusual uses for Felt. Drop us a line and we will send you a copy.

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tion may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Nov. 2-6—

American Institute of Electrical Engineers. Fall general meeting to be held at Hotel Muehlebach, Kansas City, Mo. H. H. Henline, 33 West 39th St., New York 18, N. Y., is secretary.

Nov. 9-12—

National Electrical Manufacturers Association. Annual meeting to be held at Haddon Hall, Atlantic City, N. J. Additional information may be obtained from society headquarters, 155 East 44th St., New York 17, N. Y.

Nov. 29-Dec. 4—

American Society of Mechanical Engineers. Annual meeting to be held at the Statler Hotel, New York, N. Y. C. E. Davies, 29 West 39th St., New York, N. Y., is secretary.

Nov. 30-Dec. 5—

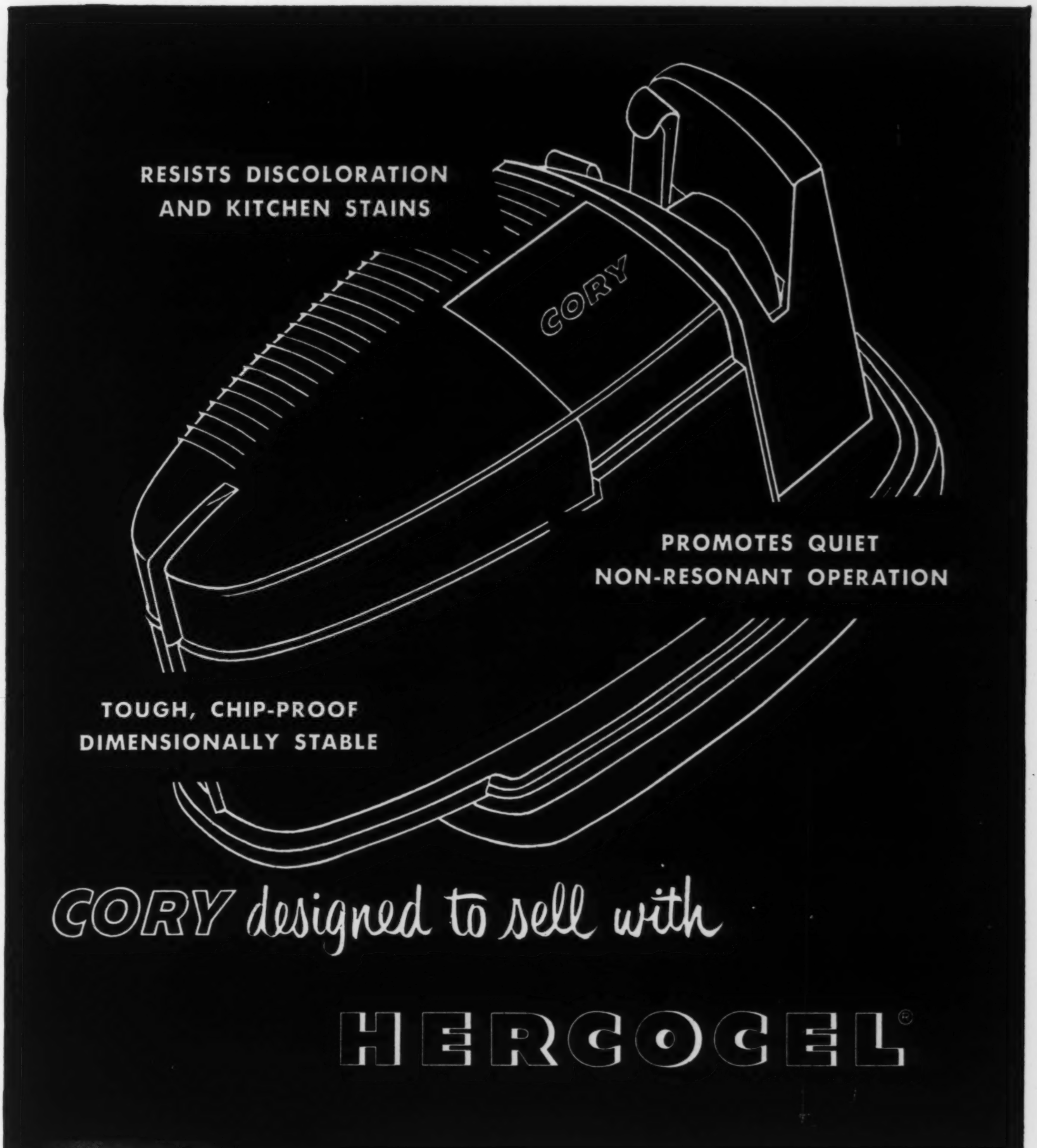
Exposition of Chemical Industries. Twenty-fourth exposition to be held at Convention Hall, Philadelphia, Pa. Charles F. Roth, Grand Central Palace, 480 Lexington Ave., New York 17, N. Y., is manager.

Dec. 13-16—

American Institute of Chemical Engineers. Annual meeting to be held at Jefferson Hotel, St. Louis, Mo. Additional information may be obtained from society headquarters, 50 East 41st St., New York 17, N. Y.

Jan. 11-15—

Society of Automotive Engineers. Annual meeting to be held at the Sheraton-Cadillac Hotel and Hotel Statler, Detroit, Mich. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.


RESISTS DISCOLORATION AND KITCHEN STAINS
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PROMOTES QUIET NON-RESONANT OPERATION
TOUGH, CHIP-PROOF DIMENSIONALLY STABLE
CORY designed to sell with
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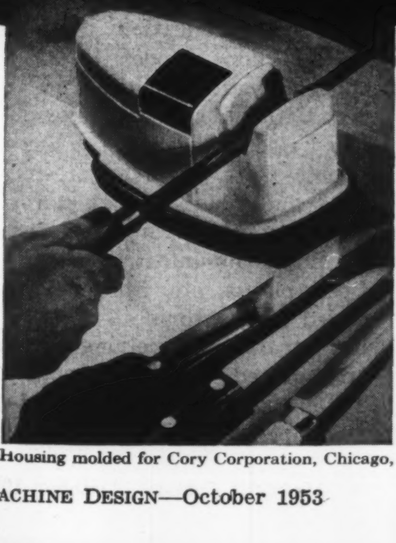

Housing molded for Cory Corporation, Chicago, Ill., by G-M Laboratories, Inc., Chicago, Ill.

Housed in Hercocel A, the new Cory Electric Knife Sharpener has everything that makes for economical production and profitable sales. The gleaming white, attractively styled housing is quickly molded in one piece. It's tough, dimensionally stable . . . proof against casual kitchen handling. The porcelain-like finish, with color through and through, is stain-resistant . . . can't chip, peel or wear off. And Hercocel, non-resonant itself, helps assure quiet operation of the unit. For complete information on Hercocel plastics, and details of the design and technical assistance offered by Hercules, write:

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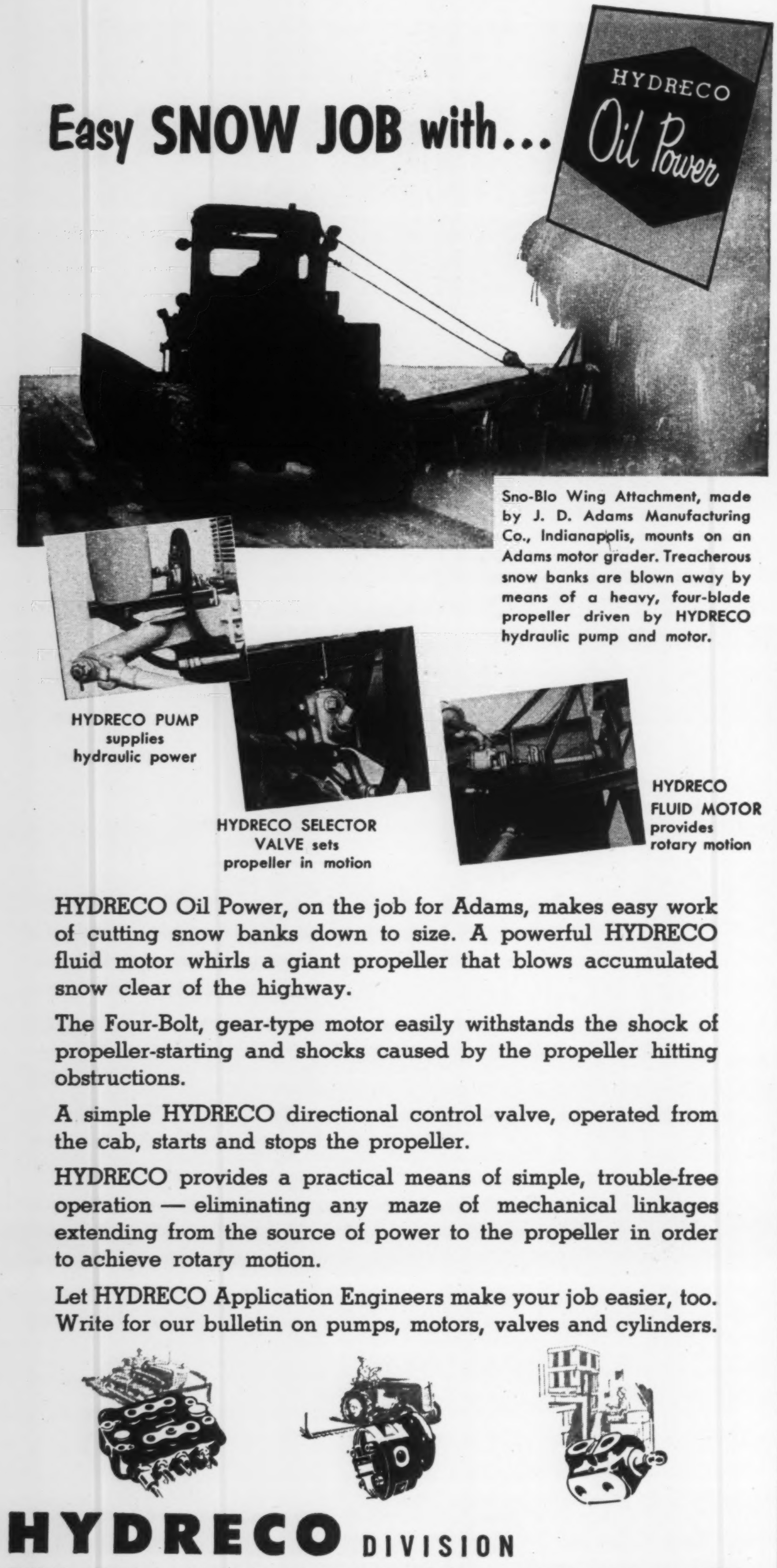

Easy SNOW JOB with... HYDRECO Oil Power

Sno-Blo Wing Attachment, made by J. D. Adams Manufacturing Co., Indianapolis, mounts on an Adams motor grader. Treacherous snow banks are blown away by means of a heavy, four-blade propeller driven by HYDRECO hydraulic pump and motor.

HYDRECO PUMP supplies hydraulic power

HYDRECO SELECTOR VALVE sets propeller in motion

HYDRECO FLUID MOTOR provides rotary motion

HYDRECO Oil Power, on the job for Adams, makes easy work of cutting snow banks down to size. A powerful HYDRECO fluid motor whirls a giant propeller that blows accumulated snow clear of the highway.

The Four-Bolt, gear-type motor easily withstands the shock of propeller-starting and shocks caused by the propeller hitting obstructions.

A simple HYDRECO directional control valve, operated from the cab, starts and stops the propeller.

HYDRECO provides a practical means of simple, trouble-free operation — eliminating any maze of mechanical linkages extending from the source of power to the propeller in order to achieve rotary motion.

Let HYDRECO Application Engineers make your job easier, too. Write for our bulletin on pumps, motors, valves and cylinders.

HYDRECO DIVISION
THE NEW YORK AIR BRAKE COMPANY
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New Machines

Communication

Amplifier: Portable Model 3717-MB, housed in a steel cabinet, has an indirectly lighted control panel. Built-in 78-rpm rim-drive phonograph with separate volume control is equipped with crystal pickup and true-balance turntable. Microphone input also has separate volume control. Power output is 15 w at less than 5 per cent; frequency response is 50 to 15,000 cycles ±2 db; power consumption is 110 w at 177 v, 60 cycles ac; 15 amp (maximum) at 6 v dc. Dimensions are 14½ in. wide, 10 in. deep, 9 in. high. Model 3717-MB3 has a three-speed motor and turnover pickup for 33⅓, 45 and 78 rpm records. *Bell Sound Systems Inc., Columbus, O.*

Magnetic Tape Handler: For digital data handling and general computer recording and playback. Starts and stops intermittently within 5 milliseconds in response to external signals and has fully reversible drive at speeds of 15 and 30 ips. Model 901A for ½-in. tape provides six-track recording; Model 901B for ¼-in. tape provides two tracks. Other models for one to eleven tracks are available for use with 2400 ft, 10½-in. diameter reels. Unit mounts on standard 19-in. relay rack, requires 24½ in. of panel space and 13 in. behind the panel. Power required is 115 v ac, single phase, 400 w. *Potter Instrument Co. Inc., Great Neck, N. Y.*

Intercommunication System: Talk-A-Phone Model LC-33 two-station system requires no wired installations; can be plugged into any electrical outlet. Features "Sonic Gate," which screens out hum and noise. Designed for instant or temporary installation; permits communication between offices, plants, etc. Stations can be added at any time, all stations being capable of receiving messages transmitted from any point. Uni-Trans system provides dictation and supervisory control; eliminates need for operating controls while dictating. *Talk-A-Phone Co., Chicago, Ill.*

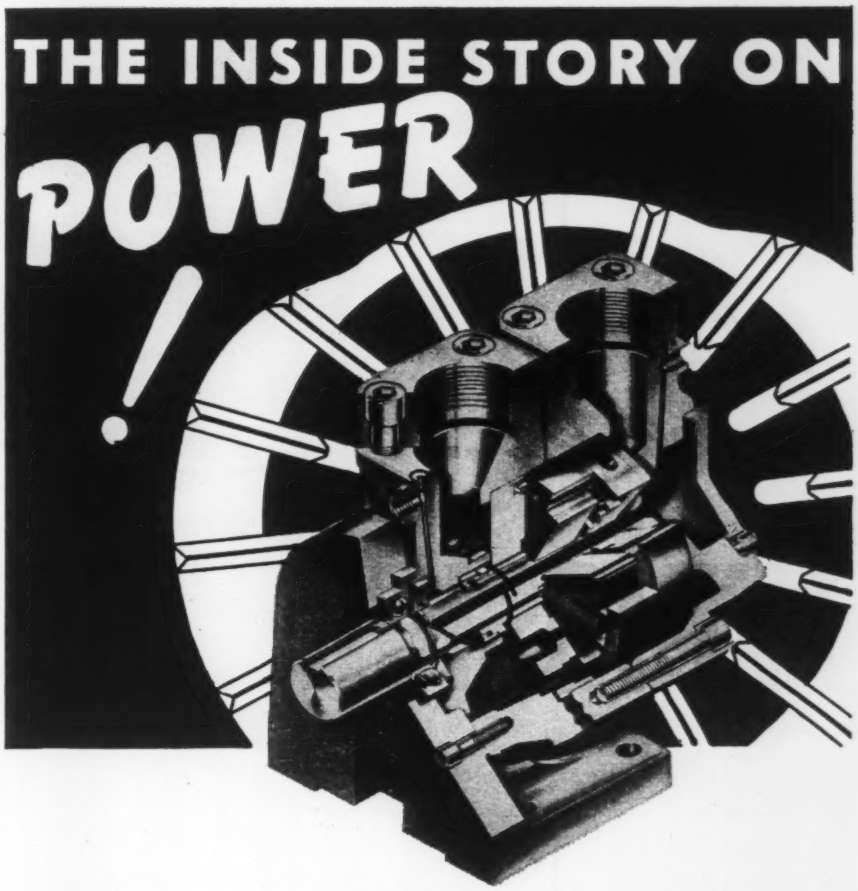
Two-Way Radios: Mobile 30 and 60-w FM models feature universal 6 or 12-v dc operation, dual interrupter vibrator power supply and greatly reduced primary power drain. Power conversion is 70 per cent efficient and is accomplished automatically in the external cabling and connectors. The T41G models have a nominal RF power output of 30 w; housings measure 6 by 9⅞ by 18¼ in. The T51G series, with nominal 60-w RF output, measure 6⅛ by 15⅜ by 20¼ in. *Communications & Electronics Div., Motorola Inc., Chicago, Ill.*

Tape Recorder: High-fidelity, automatic pushbutton console models are available with either mahogany or limed oak housings. Two-speed, dual-track unit has maximum recording time of 2 hours on both tracks of a 7-in. reel at 3¾ in. of tape per second. Features record lock button to prevent accidental erasure, forward and reverse winding mechanism which operates at ten times normal speed. Main recording unit is mounted on a sliding drawer which can be closed while a tape is being played back. An ac receptacle is located at the rear of the cabinet for plug-in of record player attachment or radio receiver. Cabinet measures 30 in. high and 22 in. wide. *Wilcox-Gay Corp., Brooklyn, N. Y.*

Domestic

Electric Range: Model J-363L features integrated backsplasher panel: surface unit and oven controls, oven timer, appliance outlets and fluorescent light are housed in or mounted on the panel. Oven is 21 in. wide, 18 in. deep and 15 in. high. Four surface units include one 1600-w extra-high-speed unit. All are of the metal-enclosed sheath type and are pushbutton controlled. Two base drawers and file type side drawer have nylon rollers and lock stops. Combined fuse receptacle and duplex appliance outlet is mounted on backsplasher panel. *Major Appliance*

(*Continued on Page* 408)



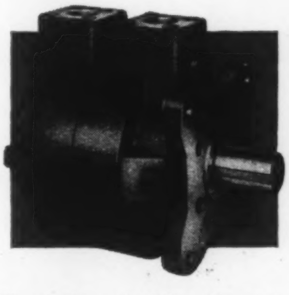
the ALL Way Balanced Dual-Vane

DUDCO

HYDRAULIC PUMP

One look at the inside of a DUDCO Pump tells the story of efficiency through *fully* balanced construction. Note how, at all times, the Dual-Vanes provide a *double* barrier to slippage and lost power. These DUDCO Vanes are individually balanced to closely follow the cam ring contour without wear-producing thrust . . . their unique displacement action provides an extra 15% to 20% added volume.

Smooth, non-pulsating DUDCO power, delivering 2000 psi for continuous operation, frequently doubles the capacity of less efficient hydraulic circuits. Standard models from 3 gpm to 120 gpm.



Featuring starting torques higher than running torques, DUDCO has long been recognized as the most efficient Fluid Motor in the field. Standard models from 180 lb. in. to 14,400 lb. in.

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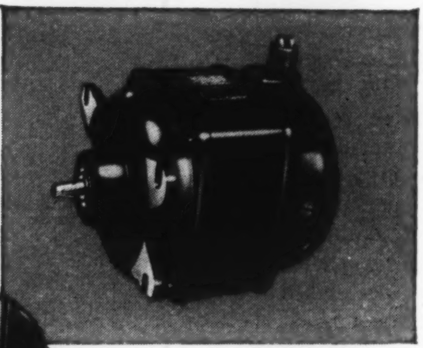
THE NEW YORK AIR BRAKE COMPANY
1706 EAST NINE MILE ROAD • HAZEL PARK • MICH.

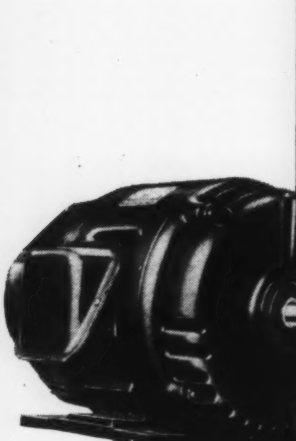
Leland explosion-proof ether pump motor.

When the specs call for...

Explosion-Proof Motors.

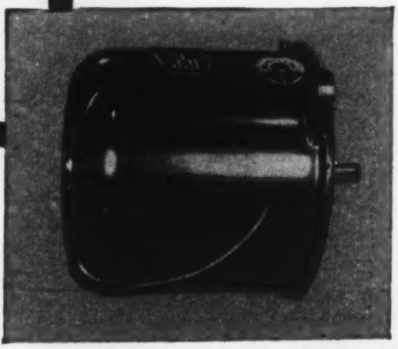


Leland explosion-proof hose reel motor.



Leland repulsion-start, induction-run standard motor in drip-proof open frame provides high starting torque for many general-purpose applications.

Leland explosion-proof gasoline pump motor.



Leland flange-mounted oil burner motor.

See AMF's new, exciting television show, "OMNIBUS", every Sunday. Check local paper for time and channel.

.. Look to Leland!

- **Pioneer developers of explosion-proof motors for many purposes.**
- **Builders of fine motors, 1/6 to 5 HP—open, enclosed, explosion-proof—various electrical types.**
- **Noted for creative engineering of electric motors for many special applications.**

Leland serves the needs of Original Equipment Manufacturers...offers them unusually close and effective engineering liaison... supplies them with motors that are not only *right* for the application, but also extremely free of service difficulties.

Since Leland engineers developed their first Underwriters' approved, explosion-proof motor 30 years ago, Leland has consistently maintained leadership in this field. Today, Leland explosion-proof motors power more gasoline dispensing pumps than all other makes combined. Low-voltage, battery-operated Leland explosion-proof motors drive hose-retracting reels on modern airport fueling and crash trucks and on fuel oil delivery trucks. Even the ether pump motors in many hospitals bear the Leland name on their explosion-proof labels.

Take advantage of Leland's wide assortment of motor types and designs, in the range from 1/6 to 5 horsepower. Whether you require an open, enclosed, or explosion-proof motor, you'll find the same high quality and dependability in a Leland motor as you have endeavored to build into your own product.

For a more detailed picture of Leland's facilities for motoring your products, please write for Bulletin 201-B.

The LELAND LE ELECTRIC Co.

DAYTON 1, OHIO

Division of AMERICAN MACHINE & FOUNDRY COMPANY, New York
In CANADA, Leland Electric Canada, Ltd., Guelph, Ontario

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To meet YOUR space and load requirements.

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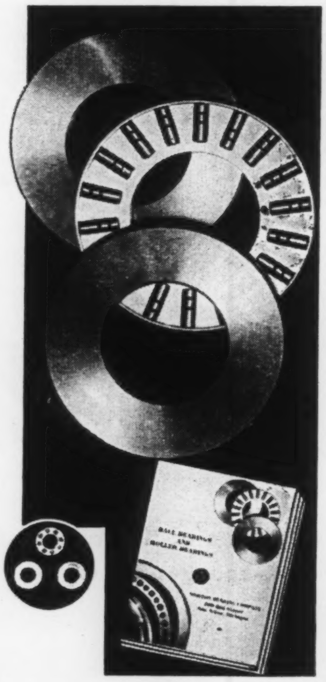
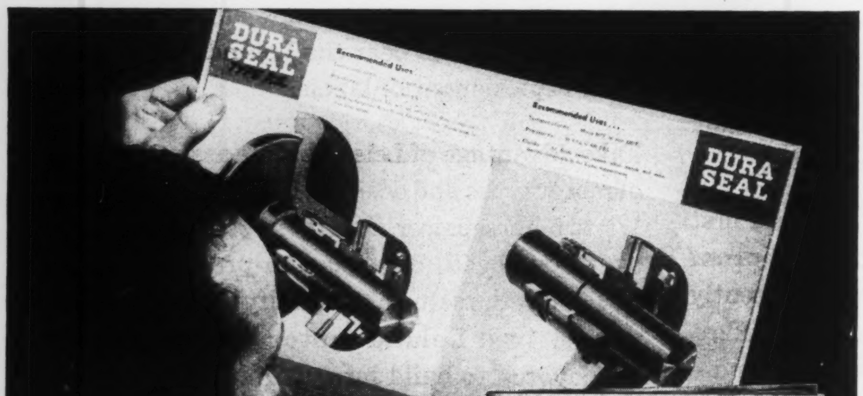
- ANGULAR CONTACT BEARINGS
- NEEDLE ROLLER BEARINGS
- THRUST BALL BEARINGS
- THRUST ROLLER BEARINGS



MORTON BEARING COMPANY recently moved to a new and larger building with additional equipment and personnel. Engineers are experienced in assisting customers in bearing design and selection to solve individual problems.

Submit data on your bearing requirements for prompt dependable suggestions on engineering, delivery, and prices. A Thrust Bearing Catalog will be sent on request.

MORTON BEARING CO.
815 Wildt St. Ann Arbor, Michigan



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A complete reference catalog on Dura Seal—the engineered mechanical seal that rotates with the shaft. Amply illustrated . . . specific applications . . . installation data. A fact book of real value to designers, operators and maintenance departments.

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DURAMETALLIC CORPORATION
KALAMAZOO, MICHIGAN

(*Continued from Page* 405)

Div., General Electric Co., Louisville, Ky.

Snow Plow: Snow Hound propels itself through snow up to 16 in. deep; clears snow at the rate of 60 shovel loads per minute. Snow is thrown from 10 to 15 ft to right or left, direction being changed by hand adjustment of chute. Powered by a 2.5-hp, four-cycle engine with automatic centrifugal clutch and 2-qt capacity fuel tank. Carburetor heater insures quick starting and prevents icing. Cast iron wheels have deep lugs for positive grip on ice or packed snow. *Toro Mfg. Corp., Minneapolis, Minn.*

Materials Handling

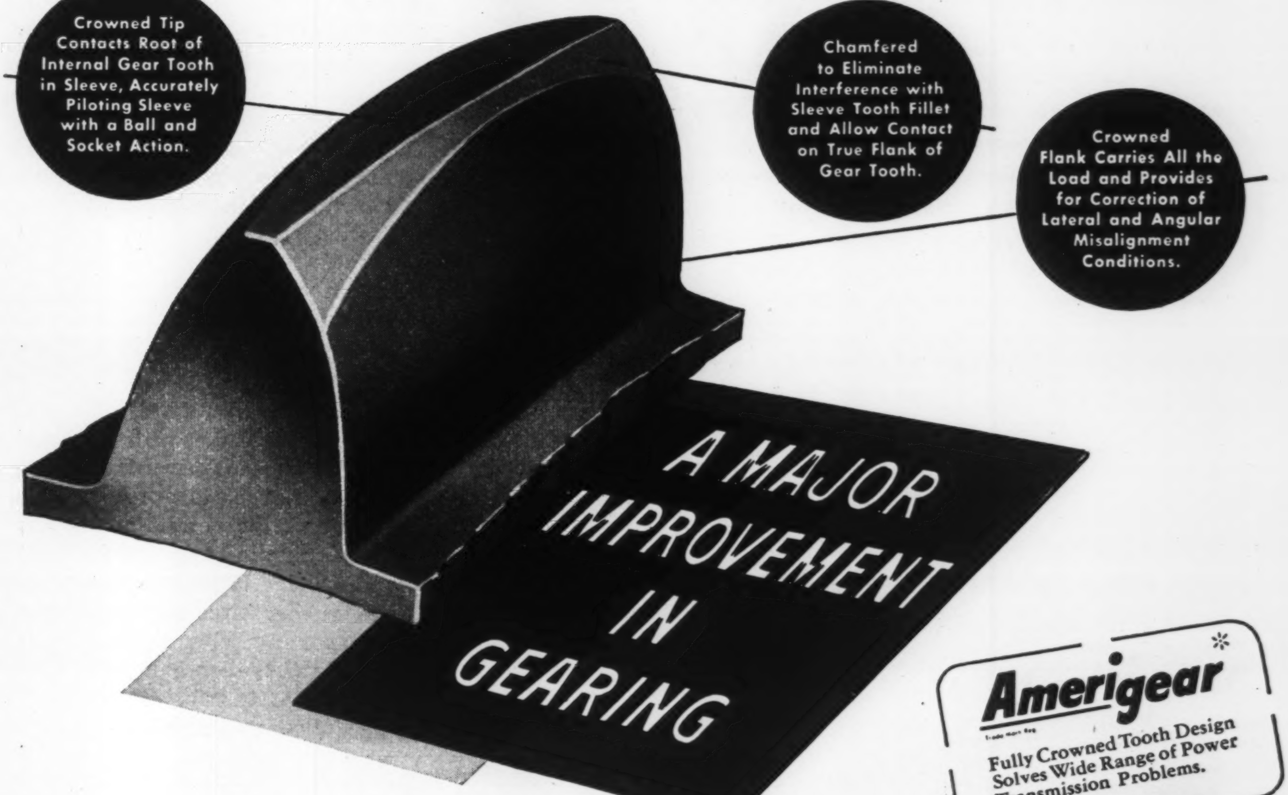
Carton and Drum Clamp: Hydraulically controlled; handles both cartons and drums without using skid or pallet. Flat, broad clamp arms which handle load units of cartons have slots which fit around ridges of drum, without interfering with rolling ribs. Four inches of lateral shift in either direction permits accurate location of clamp arms when picking up a load and accurate spotting of a load in confined quarters. Each arm of the clamp operates independently to minimize the space between loads. When used on a 2000-lb truck, clamp can handle 1800-lb loads at 14-in. load centers. Maximum clamp opening is 52 in.; minimum, 18 in. *Elwell-Parker Electric Co., Cleveland, O.*

Fork Lift Truck: FL-15, 1500-lb capacity model stacks 36-in. loads in a 6-ft aisle. Designed for ease of maintenance, all major maintenance elements are in a cowl directly under the driver's seat. Features good all-around visibility and a trailing axle for smoother running on uneven surfaces. Overall length of truck, 95 in.; width, 30 in.; height, 83 in. Turning radius, 59 in.; lift, 130 in. *Baker Industrial Truck Div., Baker-Raulang Co., Cleveland, O.*

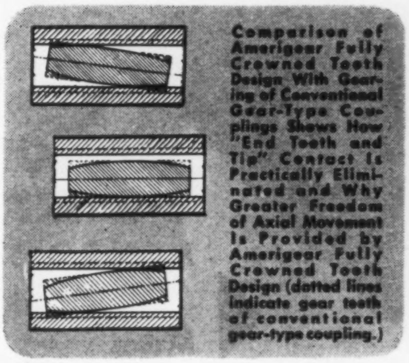
Electric Platform Lift: Vertical Lift moves materials from floor to floor where limited space prohibits use of an inclined belt conveyor. Raises or lowers 800-lb loads at

THE Amerigear* FULLY CROWNED TOOTH DESIGN

practically eliminates "End Tooth and Tip" contact . . . gives greater freedom of axial movement


Crowned Tip Contacts Root of Internal Gear Tooth in Sleeve, Accurately Piloting Sleeve with a Ball and Socket Action.
Chamfered to Eliminate Interference with Sleeve Tooth Fillet and Allow Contact on True Flank of Gear Tooth.
Crowned Flank Carries All the Load and Provides for Correction of Lateral and Angular Misalignment Conditions.
A MAJOR IMPROVEMENT IN GEARING
Amerigear*
Trade Mark Reg.
Fully Crowned Tooth Design Solves Wide Range of Power Transmission Problems.

Pat. & Pat. Pending



Comparison of Amerigear Fully Crowned Tooth Design With Gearing of Conventional Gear-Type Couplings Shows How "End Tooth and Tip" Contact Is Practically Eliminated and Why Greater Freedom of Axial Movement Is Provided by Amerigear Fully Crowned Tooth Design (dotted lines indicate gear teeth of conventional gear-type coupling.)

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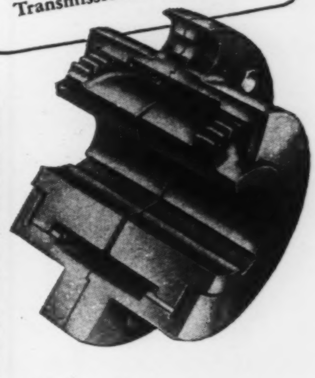

Oil Seals of Amerigear Couplings Are As Advanced in Design, Performance, and Effectiveness As Is the Amerigear Fully Crowned Tooth.

This major improvement in gearing—a fundamental improvement in gear tooth design results in these advantages: (1) Relief from extraneous stresses; (2) Crowned flanks providing for angular and lateral misalignment with back lash reduced to a minimum; (3) Torque load carried on flanks of teeth rather than on tooth edges; (4) Greater loads and higher speeds with corresponding longer life for coupling and equipment; (5) Close fit on crowned tips and flanks of teeth, inducing a ball and socket action between hub teeth and internal sleeve teeth, assure quiet and smooth performance. These advantages distinguish the Amerigear Couplings from common gear-type couplings. If your problem arises from excessive offset or angular misalignment, tight back lash requirement, space limitations, high speeds and loads, or any combination of these, the best solution is assured by use of the Amerigear Couplings with the Fully Crowned Teeth. Amerigear Engineers are available for consultation.

*Trade Mark Reg.

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ERIE, PA., U. S. A. *Originator of the Amerigear Fully Crowned Tooth*
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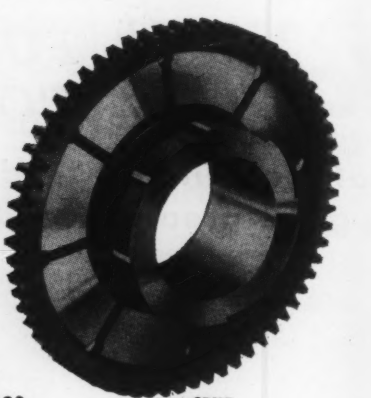
In Canada: Canadian Zurn Engineering, Ltd. • 2052 St. Catherine St. W., Montreal 25, P. Q.

American Flexible Coupling Co., Erie, Pa., U. S. A.

Please send me further information regarding AMERIGEAR COUPLINGS with the Fully Crowned Teeth and Catalog No. 501.

Name .... *Title* ....
Company ....
Address ....
City .... *State* ....
Please attach to your business letterhead.

GEARS GALORE



In over 45 years of custom-gear making, we've produced gears for thousands of different uses and products. We've made gears for diesel engines and driers and drilling equipment; for machine tools and marine drives and medical equipment—gears of all types and sizes, for all kinds of jobs. We've learned from experience that no two gear requirements are entirely identical—that each gearing problem requires a separate solution. And from this variety of experience we've gained the ability and "know-how" to produce the *right* gear for any job you might have.

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WISCONSIN-POWERED
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Switching Unit
Moves 3 Cars at a Time!

Here's a practical "locomotive" for switching and spotting cars on your sidings — at a great saving in man-hours, plus increased safety and ever-ready convenience . . . at an operating cost of about 1½ gals. of gasoline per hour!

A 25 hp. Model VF4 Wisconsin Heavy-Duty Air-Cooled Engine furnishes dependable power for all phases of HEMCO-MOTIVE operation . . . off-track mobility, climbing up and over the rails, operating the hydraulic lift that "couples" the unit to the car, and handling all switching and spotting maneuvers . . . delivering a 7400-lb. drawbar pull through 4-wheel drive, moving up to 3 loaded freight cars at a time, at a rail speed of 150 ft. per minute! Hemco Manufacturing Inc., Argonia, Kansas, is the builder.

It's another typical Wisconsin Air-Cooled Engine original equipment application . . . again illustrating how these fine engines fit both the JOB and the MACHINE.

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WISCONSIN MOTOR CORPORATION
World's Largest Builders of Heavy-Duty Air-Cooled Engines
MILWAUKEE 46, WISCONSIN

A 7550-⅛

standard speed of 15 fpm, or a 300-lb load at 30 fpm. Platform can be lowered to 6½ in. above floor level and raised to a maximum of 20 ft. Platform size is 24 by 30 in.; other sizes are available. *Rapids-Standard Co. Inc., Grand Rapids, Mich.*

Hydraulic Lift Truck: Turnabout Adjust-A-Fork features interchangeability of forks. Standard fork lengths of 30, 36, 42, 48 and 60 in. are available. Fork position width is adjustable, 25 or 27 in. Capacity is 2500 lb. Lowered height of forks is 3¼ in.; lift is 4 in. Front wheels are resinoid plastic; rear wheels are aluminum. Truck weighs 299 lb. *Rack Hydraulic Equipment Corp., Connellsville, Pa.*

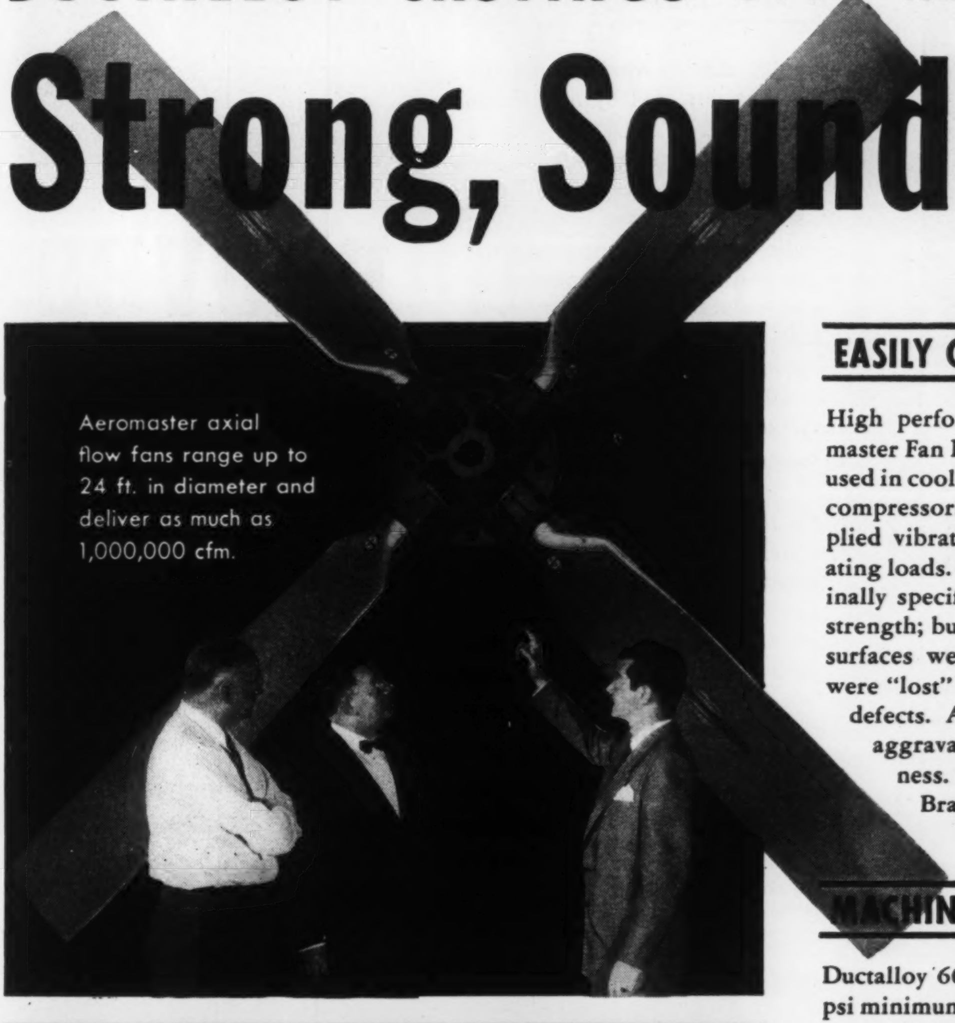
Heavy-Duty Lift Truck: Four-wheel drive Baker-Lull Forkloader has five speeds forward and five reverse. Large, low-pressure high-flotation tires permit operation on rough terrain, and in mud, snow and sand. High operating speed and rubber tires make truck self transporting, eliminating need for truck and trailer hauling. Lifting capacity is 6000 lb. Series includes the following models: 60N, front wheel steer, gas powered; 61N, front wheel steer, diesel powered; 62N, rear wheel steer, gas powered; 63N, rear wheel steer, diesel powered; 64N, four wheel steer, gas powered; 65N, four wheel steer, diesel powered. *Baker-Raulang Co., Cleveland, O.*

Die Handling Truck: Electric; moves dies which weigh up to 1 ton. Has hydraulic push-pull device for die placement or removal at storage racks or flat bed presses. Angle winch facilitates loading at inclined presses. Truck is capable of right-angle stacking in a maximum aisle space of 76 in. Die handling platform consists of a removable 24 by 30-in. plate which rests on adjustable forks. Forks can be lengthened from 9¼ to 30¼ in. Available in a telescopic model, which elevates to 130 in., and a nontelescopic model with 100-in. elevation. *Raymond Corp., Greene, N. Y.*

Fork Lift Trucks: Load capacity is 6000 lb at 24-in. load center. Available with 72, 84, 108, 114 and 120-in. lift heights and with dual

DUCTALLOY® CASTINGS GIVE KOPPERS FANS

Strong, Sound Hubs



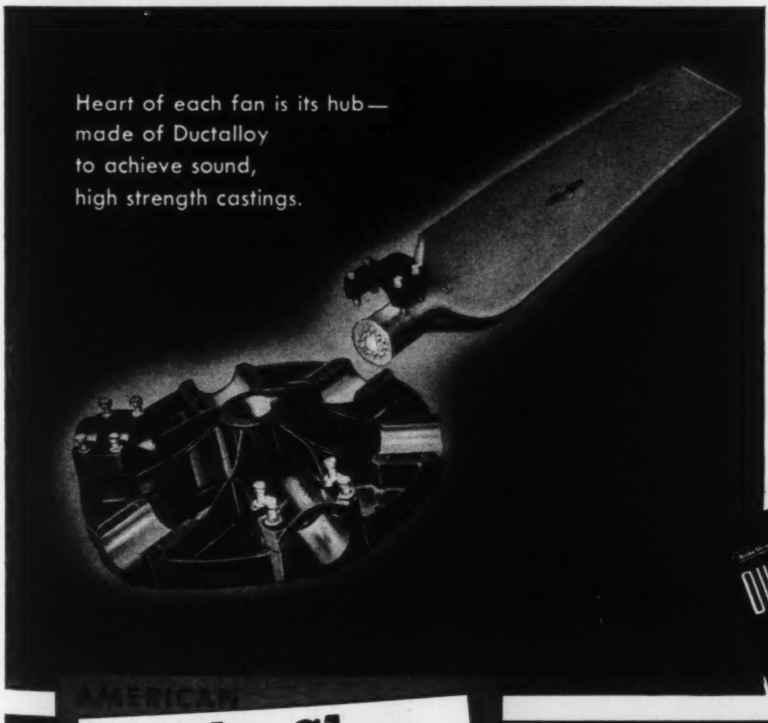
Aeromaster axial flow fans range up to 24 ft. in diameter and deliver as much as 1,000,000 cfm.

EASILY CAST, EASILY MACHINED

High performance fans made by the Aeromaster Fan Department of Koppers Company, used in cooling towers near diesel engines and compressors, must withstand considerable applied vibration in addition to normal operating loads. For this reason cast steel was originally specified to provide the necessary hub strength; but machining costs were excessive, surfaces were poor, and too many castings were "lost" when machining revealed hidden defects. A switch to malleable iron only aggravated the problem of casting soundness. The answer was Ductalloy 60—Brake Shoe's easily machined high strength ductile cast iron.

MACHINE SHOP REJECTS ENDED

Ductalloy 60 is a ferritic iron having 60,000 psi minimum tensile strength, 40,000 psi minimum yield strength and 10% minimum total elongation, all guaranteed. Use of this material has virtually eliminated the high scrap loss formerly encountered when defects were uncovered during machining of castings made in either steel or malleable iron.



Heart of each fan is its hub—made of Ductalloy to achieve sound, high strength castings.

your problem — Ductalloy may solve your problem if it involves economical production of complex metal shapes that are difficult to cast in steel, expensive to forge or lacking strength in gray iron. Brake Shoe's experience, research laboratory and experimental foundry are available to help you best utilize Ductalloy's unusual combination of characteristics. Write for this new technical bulletin today.

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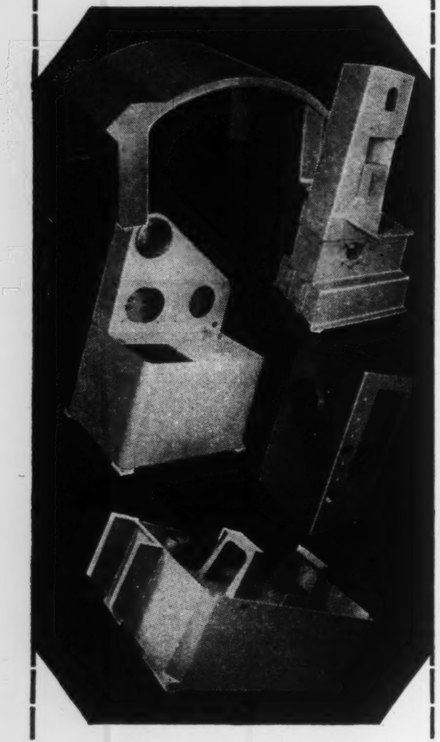

Weldments, Bases and Sub-Assemblies fabricated by Littleford give Economy, Strength, Permanence, Adjustability and Low Cost. Fabricated Products speed up production by eliminating machining operations and expensive patterns. To produce modern plate and sheet metal products also requires experience and skilled craftsmen; this is where Littleford definitely fits into the picture. Since 1882 Littleford has developed craftsmen to shear, bend, form, weld and finish plate and sheet metals. Using modern methods and modern machines, Littleford Weldments, Bases and Sub-Assemblies are the last word in accuracy.

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PLATE AND
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PRODUCTS
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If you have a problem involving Weldments, Bases or Sub-Assemblies, remember there is no substitute for experience, send your blueprints to Littleford, see how skill can produce low-cost products.

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or single drive wheels. Model FTP60-24 is powered by a gasoline engine; Model FTPD60-24, by a diesel. Features include a single lever, automotive type, full range gear shift; center-point steering; hydraulic brakes, self aligning lift cylinder and a carriage mounted on quick-adjustable side thrust, antifriction rollers. Overall length without forks is 104¾ in. for dual drive, 106¼ in. for single drive unit. *Buda Co., Harvey, Ill.*

Railway Car Switcher: Redesigned Trackmobile moves railway cars for loading, unloading and general handling operations. Travels on rubber wheels mounted at right angle to body. Road wheels are retracted and track wheels are lowered onto rails for use. Unit has four speeds for travel in either direction. Powered by four cylinder gasoline engine. Overall dimensions on track: length, 85 in., width, 118 in.; height, 70½ in. *Whiting Corp., Harvey, Ill.*

Hydraulic Lift Table: Available in 4000 and 10,000-lb capacities. Raises to 43 in., offering 30½ to 34 in. of usable lift. Table top measures 36 by 84 in. In lowered position, height is 12½ in., but it can be reduced to 9 in. if hydraulic pump unit is mounted outside the unit. Controlled by foot-operated levers mounted at table end; remote control by means of two pushbuttons can be furnished. Uses include sheet feeding. *Beacon Machinery Inc., East St. Louis, Ill.*

Electric Hoists: Available in capacities of 1000, 2000 and 4000 lb. Standard lift is 10 ft. Have 12-v motors and controllers and may be installed on trucks equipped with 6-v electrical systems by adding another 6-v battery. Draw minimum current from the battery; normal truck operation provides recharging. *Shaw-Box Crane & Hoist Div., Manning, Maxwell & Moore Inc., Muskegon, Mich.*

Fork Lift Truck: Model D-424 has 4000-lb capacity at 24-in. load center. Powered by a Chrysler six-cylinder, 65 bhp industrial engine. Power transmission system features heavy-duty multiple disk clutch which transmits power from the engine to the drivewheels. One-

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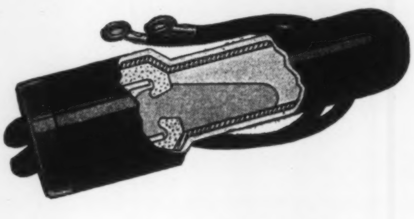

Durakool pressurized all-steel **mercury tilt switches** have more than made good on what may have seemed like extravagant claims a few years ago. The list of Durakool successes grows each year. Seven sizes, 1 to 65 amperes. 3 to 4 weeks delivery. Your production schedule is met.

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HIGH
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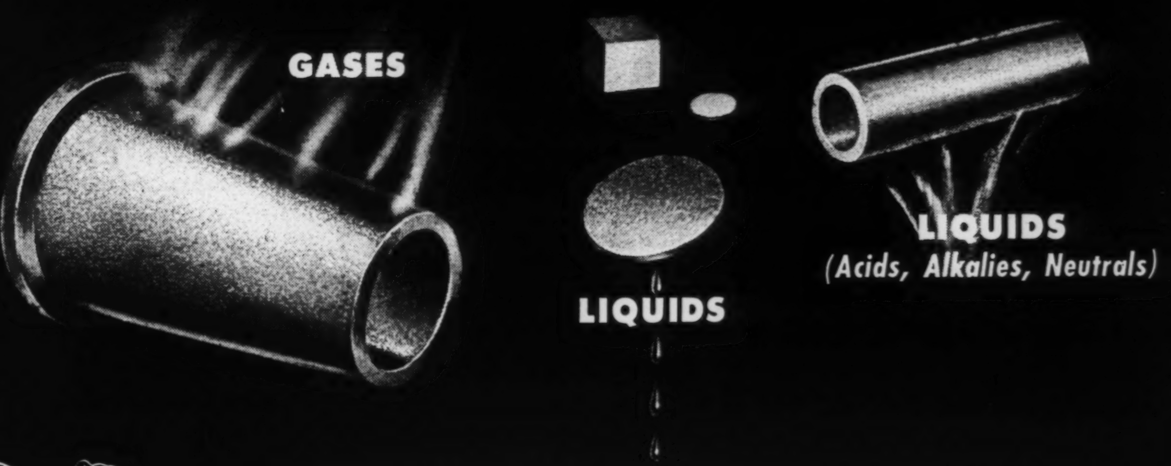
Permanent METAL FILTERS

Oilite PERMANENT FILTERS Provide:

- Durability, Strength, Fool Proof Operation, and Savings
- Filtering of Liquids and Gases
- Broad Range of Permeability, or Pore Size
- Effective Dampening, Diffusing, Regulating, Separating, Flame Arresting, and Metering
- Made of the Metal the job requires
- Small, Medium and Large Sizes, too
- Low Part Cost



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Amplex Division, Dept. D
DETROIT 31, MICHIGAN

FIELD ENGINEERS, DEPOTS AND DEALERS THROUGHOUT UNITED STATES AND CANADA

Oilite Products Include: Bearings, Finished Machine Parts, Cored and Solid Bars, Permanent Filters and Special Units

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Get absolutely
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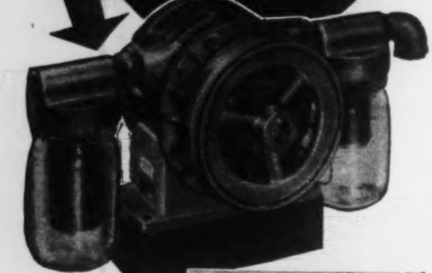
AIR
with GAST rotary
OIL-LESS
AIR PUMPS



Above — Oil-less Model 1550 — 8 to 10 C.F.M.
Right — Oil-less Model 3040, end plate removed. From 17 to 24 C.F.M.

Three things about these pumps are outstanding:

FIRST — They run *entirely without oil* in the pumping chamber. Four carbon vanes in rotor lubricate themselves — through thousands of hours of operation. Ball bearings are greased and sealed for life. You can *forget* oiling problems!

SECOND — They completely eliminate oil-mist in the air delivered. Used for *both* vacuum and pressure they *can't* contaminate your product or material with oil droplets.

THIRD — They're built with traditional Gast precision — for years of high performance and dependability.

IF THESE QUALITIES offer solutions to your original equipment problems, write Gast. Oil-less models from 10 to 20 inches vacuum — 3 to 10 lbs. pressure — 3.5 to 24 C.F.M.

see our CATALOG in SWEET'S FILE for PRODUCT DESIGNERS

Write for new Data Sheet on Oil-less Pumps, showing 3 types and rating tables.

Original Equipment Manufacturers for Over 25 Years

GAST ROTARY

AIR MOTORS • COMPRESSORS • VACUUM PUMPS
(TO THREE H.P.) (TO 30 LBS.) (TO 28 INCHES)
GAST MANUFACTURING CORP., 107 Hinkley St., Benton Harbor, Mich.

piece hood provides access to engine compartment. Overall length of truck, without forks, is 82½ in.; width, 39 in. Standard mast height is 83 in.; lifting height is 108 in. *Mobilift Corp., Portland, Ore.*

Metalworking

Press Brakes: Model 600 has a 72-in. bed plate; Model 800, a 96-in. bed plate. Both feature precision ram adjustment, balanced flywheel which runs on ball bearings, adjustable variable speed drive and 1½-hp motor, foot treadle adjustable to any position of bed with uniform action at any point. Die holder is included as standard equipment. Size of machine: 79 in. high, 44 in. deep, 66 in. wide. Die area of 12 in. shut height is provided with a 3-in. stroke and 4½ in. adjustment of stroke. Variable range of 16 to 40 strokes per minute is obtained by handwheel adjustment. *Service Machine Co. Inc., Elizabeth, N. J.*

Aluminum Pipe Welder: Employs Aircomatic welding process for field welding of aluminum gas gathering lines and oil transmission lines. Consumable 43S aluminum wire is fed to welding nozzle, where wire, weld and base metal are protected from oxidation by a shield of inert gas. Windshield around nozzle insures complete gas shield for outdoor welding. Constructed of cast aluminum; weighs approximately 200 lb; measures 4 ft in diameter by 2½ ft in width. Machine is clamped to the pipe and encircled by the welding gun by means of a motor-driven worm gear. Welds 4, 6 and 8-in. OD piping having ⅛ to ¼-in. wall thickness. *Air Reduction Co., New York, N. Y.*

Chucking Machine: Single-spindle automatic model 2-AC features front and rear cross slides and a five-faced overhead turret. Handles work up to 10¼-in. diameter and up to 9 in. turned length. Tripblocks are positioned in the slots of a pentagonal drum at rear of turret shaft to control feeds, spindle speeds, length of cutting stroke and skip indexing. Either or both cross slides can be selected to operate with any or all turret faces; Al-

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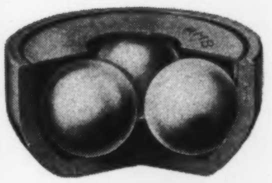

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Ball Bearings
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An RMB First

These bearings, developed by RMB, are not toys. Type C1, and the other ten sizes in the C series, are hard-working components of—

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- Scales and Gauges
- Small gear trains for clockwork
- Vibration Pick-ups
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—anywhere a miniature bearing is needed to reduce friction, where space is at a premium.
Bring your miniature bearing problems to RMB.
A complete line of over 250 miniature and instrument bearings including radial and roller types available for prompt delivery. Experimental quantities from stock.

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RMB LANDIS & GYR,
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NEW Thomas electro lead alloy coated strip steel solders readily, resists corrosion, fabricates easily

The newest addition to the Thomas family of pre-coated steels—*electro-plated lead alloy cold rolled strip steel*—gives you another method of improving your products and reducing your costs. The homogeneous and dense lead-tin alloy coating provides excellent resistance to corrosion, improves the soldering and spot welding qualities of the strip.

The ease with which Thomas Electro-coated lead alloy can be soldered without an acid flux and with a minimum consumption of solder is a distinct advantage to the fabricator. It retains its solderability over a considerable period of time. The coating also provides an excellent base for paints and synthetic enamels and acts as a lubricant in drawing operations.

Thomas Electro-coated lead alloy is available in the gauge range of .005 to .050 up to 20″ in width. For information on this new product and the other economical Thomas pre-coated steels listed below, write today.

Cold-rolled strip steel electrolytically pre-coated with Zinc, Copper, Brass, Nickel and Lead-Alloy in Natural, Planished and Buffed Finishes—Hot Dip Tin and Lead-Alloy Coated—Lacquer Coated in Colors—Annealed Spring Steel—Alloy Strip Steel—Uncoated Strip Steel. Carefully produced to your specifications.

Thomas Strip

Thomas Strip Division

Pittsburgh Steel Company • Warren, Ohio

In tomorrow's
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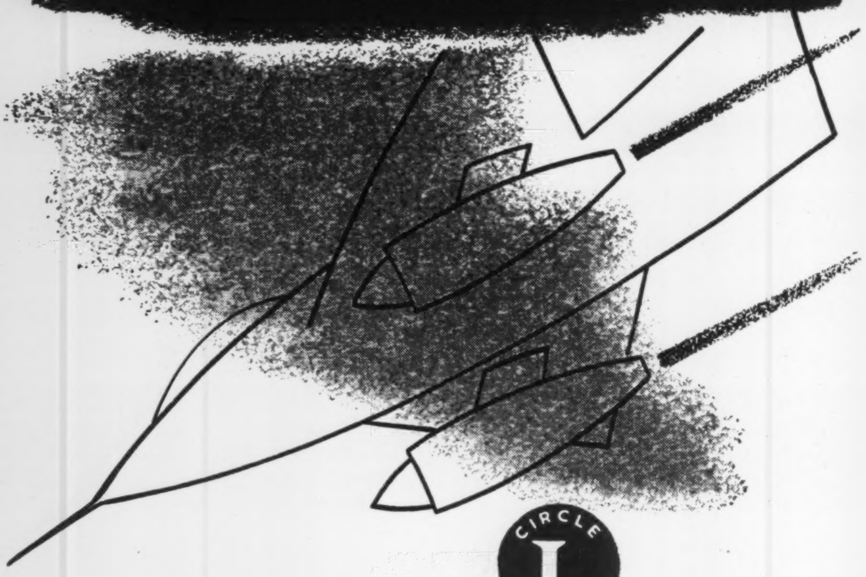
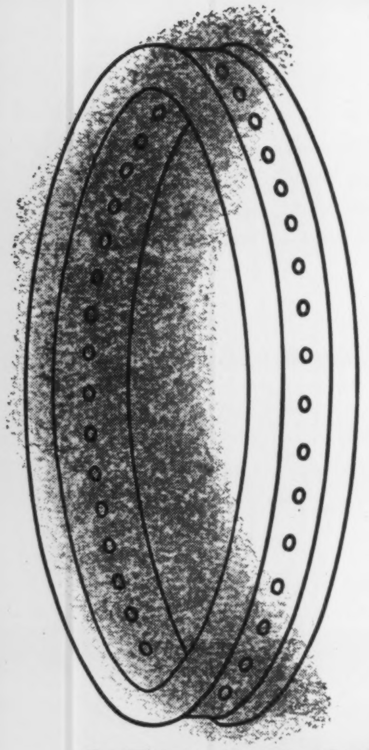


LEBANON Castings
are at work

Lebanon Steel Foundry, the largest producer of centrifugal castings for jet engines, is proud to have collaborated with the Wright Aeronautical Division, Curtiss-Wright Corporation, in developing this unusual one-piece casting. It incorporates many holes cast to size and in accurate locations, requiring no machining. Of special high-strength alloy steel, this piece is quite large in size and is designed to operate satisfactorily under high temperature conditions in one of Wright's newly-designed power plants.

Lebanon Steel Foundry supplies castings to Wright for the J-65 (Sapphire) turbojet engine, which is now in production, and is producing experimental parts for the company's other advanced jet power plants.



LEBANON Castings
CARBON, SPECIAL ALLOY
AND STAINLESS STEEL

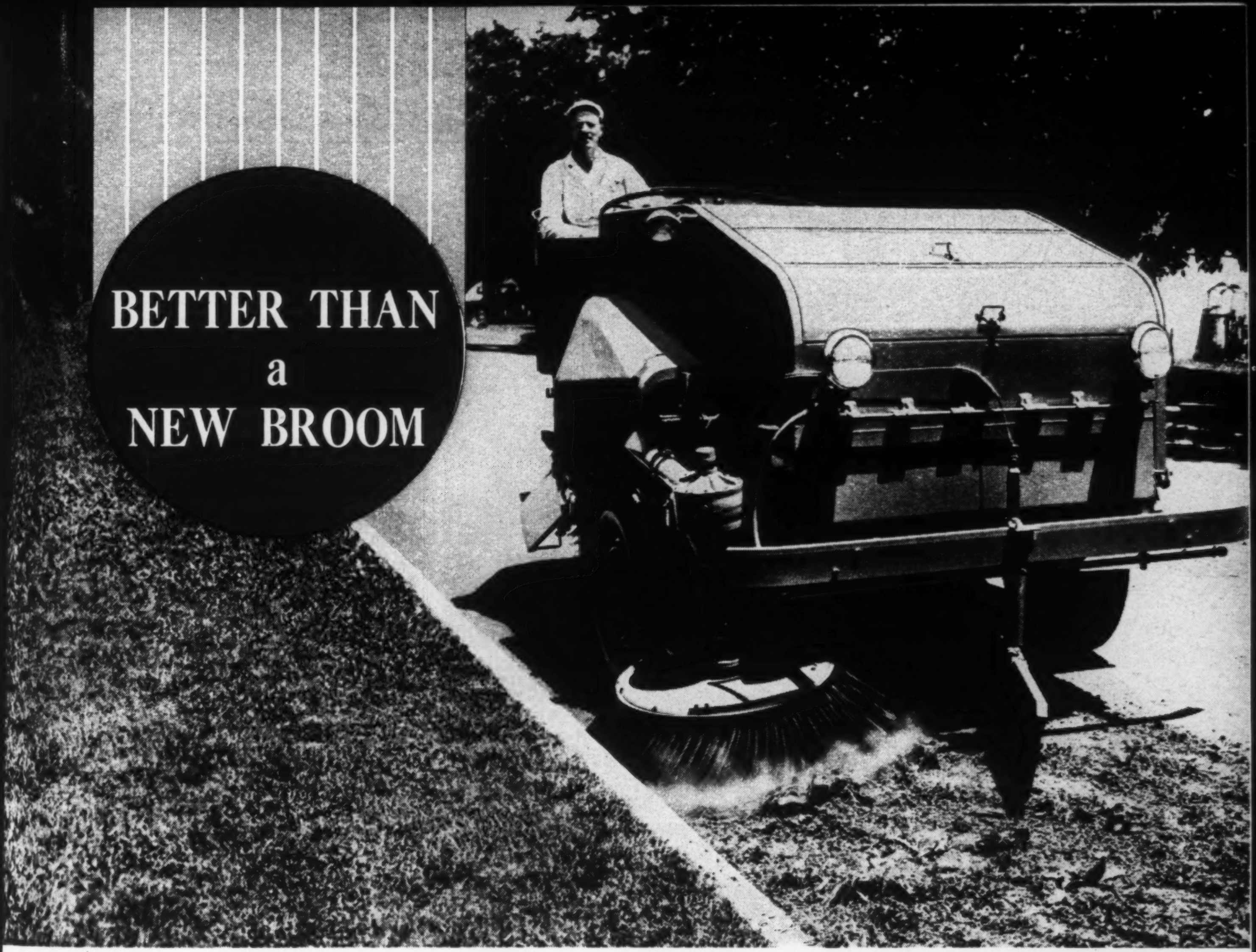
LEBANON STEEL FOUNDRY LEBANON, PA.

len wrench adjustment controls late and dwell cross-slide operation. Cam changes are not necessary. Because of the overhead turret, tool overhang on larger diameter work is eliminated; as work diameters increase, tools are brought closer to guiding ways. Spindle speed ranges from 40 to 1102 rpm and six automatically selected speeds are available in either of two ranges. Thirty-six feeds from 0.0019 to 0.124-in. are available, from which six can be automatically selected. Either or both 8-in. wide cross slides can be operated with any of the turret faces, feeding at the same rate. Maximum slide travel is 4½-in. *Warner & Swasey Co., Cleveland, O.*

Open Yoke Press: Does work of standard shop press, regular forcing press and regular platen press. Available in 100, 200, 300 and 400-ton capacities. Machined V-blocks are centered in yoke member groove. Wear collar is supplied for inserting in yoke recess, and a bed plate insert covers recess and provides continuous flat working surface. Features movable cylinder with locking device to provide full pressure across width of press, open ends to permit entrance of long material, hand-operated winch to raise or lower bolster and either hand-operated or power-driven hydraulic pumps. *Rodgers Hydraulic Inc., Minneapolis, Minn.*

Borer-Profiler: Alfing model HF1/1000 for boring and internal profiling of engine parts. Drilled shaft is placed in machine and boring bar fits into bearing preformed of fast hardening matrix, which is cut away as hole is profiled. Tool is hydraulically controlled to follow the profile of a template mounted on the machine. Chips and matrix are forced out of the hole by coolant under pressure. *Morey Machinery Co. Inc., New York, N. Y.*

Threading Machine: Landmaco, for heavy-duty precision threading on large diameter work, cuts bolt threads from 1½ to 6⅝-in. diameter and pipe threads from 1 to 6 in. diameter up to 29 in. long with leadscrew and 30 in. without leadscrew. Capacity ranges from



BETTER THAN
a
NEW BROOM

Photo courtesy Wayne Manufacturing Company, Pomona, Calif.

Chrysler powers "One-Man Sanitation Department"

For only a few cents a mile—where it used to cost dollars—any community, plant or airport can keep its streets, parking lots or air-strips clean. Thanks to the combination of modern equipment and *modern* industrial power, what once was an expensive 3, 4 or 5 man job, is today done better, faster and at far less cost . . . by one man.

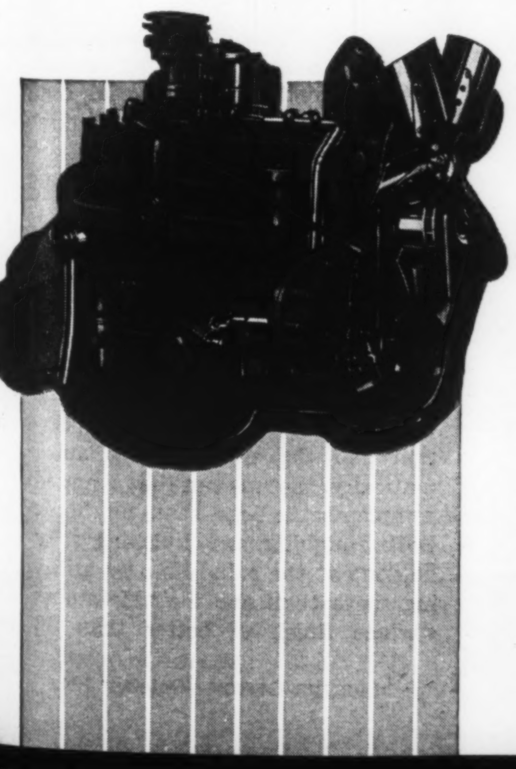
With power from a power-packed Model 8 Chrysler Industrial Engine equipped with heavy-duty, four-speed transmission, the Wayne Pick-Up Sweeper does everything in one operation. There's no need for others following behind to pick up dirt and truck it away. It sweeps up to 8 miles an hour, fills its own three cubic yard hopper as it goes along, and carries dirt away to the disposal point at traffic speeds.

This manufacturer, like others, selects Chrysler engines *equipped at the factory to meet his needs in the field.* Among the Chrysler options for his selection are gasoline, natural or liquid-propane gas burning carburetors, standard or gear driven front ends (with magneto or hydraulic pump drive), 12 or 24 volt electrical system.

See the Chrysler Industrial Engine dealer nearest you for complete information on Chrysler power. And remember, Chrysler engines are not expensive. Production-line methods, adapted to specialized Industrial Engine building, provide a custom-built engine at mass-production prices. If your problem is special, write: **Dept. 51, Industrial Engine Division, Chrysler Corporation, Trenton, Michigan.**

CHRYSLER
Industrial Engines

HORSEPOWER WITH A PEDIGREE



HOT Spinning

The Phoenixspun Way

Completes Forming of
3/8-Inch Thick "X-4130" Steel Part
To Achieve Economy . . . Speed Delivery

The defense-related part here illustrated was originally made from solid bar stock requiring excessive machining hours to rough out. High material cost of "X-4130" steel was also a factor. Forging was impractical because of excessive die costs and the limited number of pieces required.

PHOENIX solved the problem with a combination of hot press forming and hot spinning. Wall thickness was maintained within tolerances which enabled complete final machining, in minimum time.

This method has proved equally adaptable to forming of heavy-gauge experimental development and short run production of aircraft parts, ordnance items — rockets, guided missiles—automotive and truck housings.

Avail yourself of PHOENIXSPUN counsel and service for YOUR forming problems.

METAL SPINNING
(Up to 108")
DEEP DRAWING
(To 350 Tons)
WELDING
(Inert Gas, Arc, Oxy-Acetylene)
FABRICATING
ASSEMBLING

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For Product Designers

Metal Spinning Div., PHOENIX PRODUCTS CO.
4719 N. 27TH STREET • MILWAUKEE 16, WISCONSIN

2 to 24 threads per inch. Bed is equipped with hardened and ground rectangular ways. Carriage front or vise design assures proper work alignment under gripping pressure, providing 60 per cent more gripping efficiency than previous vises. Single gear shift lever provides rapid speed change of 25 per cent for any given spindle speed as determined by the speed change gears in use. Three pairs of speed change gears provide 12 spindle speeds ranging from 9 to 152 rpm. Machine is equipped with either 4 or 6-in. die head. Both provide rigid support for chasers. *Landis Machine Co., Waynesboro, Pa.*

Shear: Giant Model Tru-Edge does contour and straight inside and outside shearing, beading, louvering and joggling. Capacity is 9/32-in. mild steel. Eliminates resistance to feeding and turning the work; feeding may be started while ram is operating. Inside cutting requires no starting holes. Machine cuts from 10 to 36 fpm, depending on gage and material. Throat depth is 36½ in. *Wales-Strippit Corp., North Tonawanda, N. Y.*

Hole Drilling Machine: Drills radial holes in a variety of parts. Employs up to eight automatic drilling units which are movable through 360 degrees on the circular table as well as movable endwise on riser plates to meet requirements of the part being drilled. May also be used for tapping operations. Has a range of 1/32 to ⅜-in. on drilling operations and 0-80 to ⅜-16 on tapping operations, depending on material and spindle speeds. A single momentary contact start button actuates all units simultaneously. *Govro-Nelson Co., Detroit, Mich.*

Hydraulic Copying Lathe: Developed in France by H. Ernault Batignolles, Pilote lathe is completely automatic. Operator loads machine and presses a button to start the cycle. When part is finished, the tool returns to its starting position and the spindle stops automatically. Setup can be changed completely in less than an hour. Both roughing and finishing may be done at the same time by utilizing more than one tool. Maintains surface finish of better than 32

• VIBRATION
• FATIGUE
• IMPACT
• SHOCK

Lamson PLACE BOLTS will solve it

The Lamson Place Bolt answers many fastener problems where vibration is a factor.

Special slots in the head of the bolt plus a circular recess around the under side of the head combine to provide spring or locking action of the head against the tapped material. As the bolt is tightened the segments of the head are forced inward, this flexibility adds to the elasticity of the shank and the locking efficiency of the bolt.

The slotted Place Bolt can carry as much load as a conventional bolt because the shear section of the head is stronger than the tensile stress area of the thread.

HOW PLACE BOLTS MAINTAIN TENSION

It is well known that bridges are constructed to "give" when encountered by high-velocity winds and that the strongest buildings are not rigid in construction, even successful boxers learn to roll with the punch. This same principle governs the design of the Place Bolt.

The flexible area between the slotted segments in the upper face of the bolt head and the recess adjacent to the shank in the lower face acts as a controlled spring element. The amount of "spring" is in proportion to the wrenching torque applied.

Tension is maintained because the elastic flexing of the head, added to the overall elastic elongation of the shank, permits greater loss in clamping distance before tension drops to zero. At the same time, ability to resist shock is greatly enhanced by the added elasticity.

For the whole story, send for the Lamson Place Bolt folder.

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PLUG NUTS
Ideal for blind or hard-to-reach places.

PIPE PLUGS
Forged steel, heat-treated.

"1035" SET SCREWS
Cup point type, hardened and heat-treated.

PLACE BOLTS
With "Built-in" spring action for positive locking.

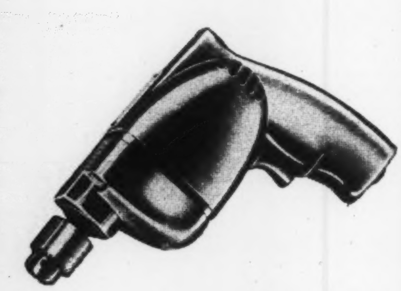
LOCK NUTS
Economical, vibration proof. Can be used repeatedly.

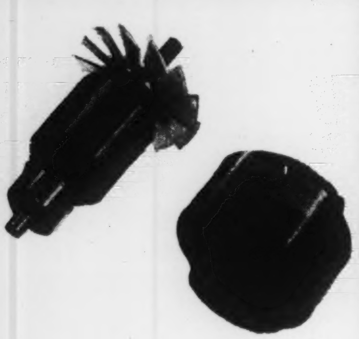
"BENT BOLTS"
Including U bolts, eye bolts, hook bolts, etc.

MACHINE SCREWS
Clutch and Phillips recessed head screws.

SEMS
Pre-assembled lockwashers on tapping and machine screws.

HOWARD
motor parts set





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ball-rite drill

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Universal and Direct Current 1/1000 to 1/2 h.p.
Shaded Pole 1/2000 to 1/8 h.p. • Induction 1/1400 to 1/4 h.p.
Dynamotors • Blowers • Motor Parts Sets • Gear Motors

Cummins-Chicago Corp., nationally famous manufacturer of business machines and portable tools, has selected EMC Model 150 motor part sets for the new Ball-Rite 44 Drill.

Mr. Otto Downer, Vice-President and Chief Engineer for Cummins, states: "The 'Heart' of the Ball-Rite 44 Drill (for that matter, any Cummins drill) is the motor. We find that the EMC motor meets our exacting requirements with respect to workmanship, durability and excellent performance under heavy work load."

EMC and CYCLOHM fractional h.p. motors, motor parts sets, dynamotors and blowers are used by hundreds of leading manufacturers for hundreds of applications — portable tools, business machines, sewing machines, electronic equipment, jet aircraft, radar and others. If you have an application requiring fractional motors, check with Howard today.

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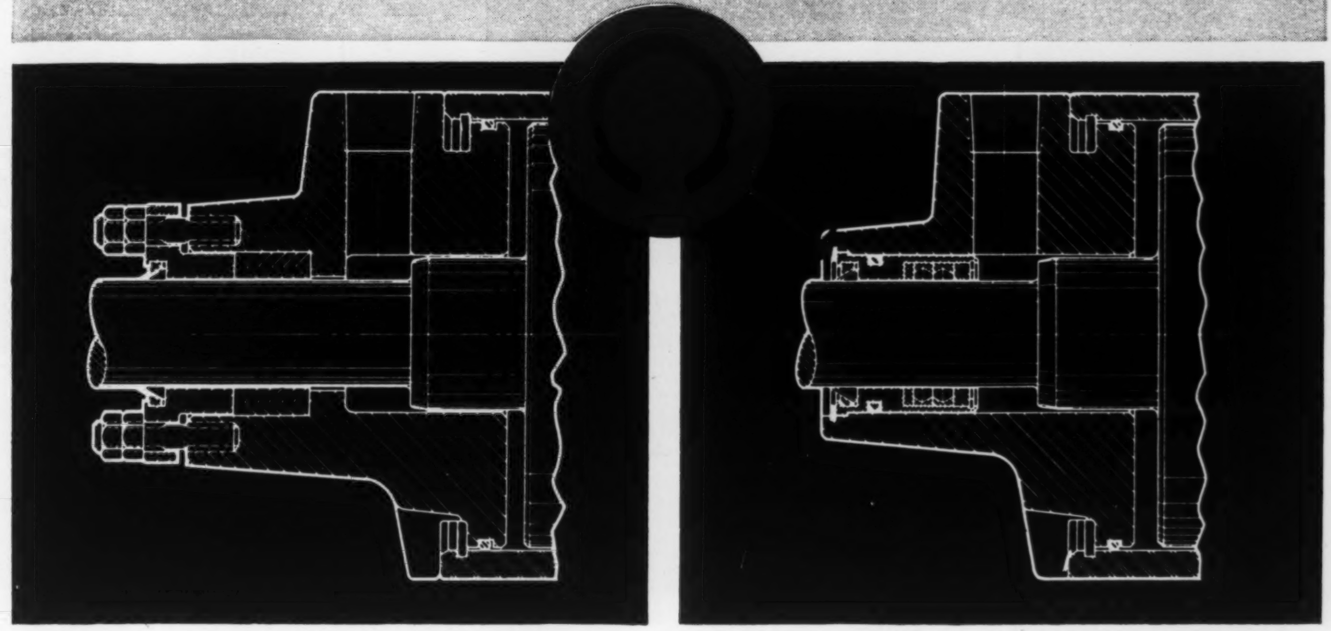
microinches. Cross-slide is arranged at 90 degrees to the bed and provided with slots so that it can be equipped with both front and back tools as well as a boring bar. Transverse motion of cross-slide is controlled hydraulically by the copying device. Machine has hydraulic carriage feed, is driven by a 20-hp motor and has spindle speed range of 380 to 3000 rpm. Feed range is from 0.0015 to 0.035-in. Maximum center distance is 30 in.; spindle bore is 2 in. A larger model has 3-in. spindle bore. *H. E. B. Machine Tools Inc., New York, N. Y.*

Bar Machine: For production of nut blanks $\frac{1}{4}$ to 2 in. diameter. Both bar stock and drils rotate simultaneously in opposite directions, speeding machining operation and assuring concentricity of the tap-drill hole with the body of the nut. Two tools perform cutting-off operation. Chuck mechanism is actuated by the centrifugal force of rotating weights rather than by cam action, insuring positive locking of the chuck pads on any size stock. Stock with as much as 1/32-in. variation across flats is chucked securely without changing chuck pads. *Miller Glass Engineering Co., Columbus, O.*

Tube Flarer: Model 232A produces concentric, smooth surfaced 37-degree tube flares for use with standard Triple-lok and AN tube fittings. Flares meet AN, JIC, SAE Hydraulic and ASME standards. Machine flares standard tube wall thicknesses and all tube sizes from $\frac{1}{8}$ through 2 in. OD; handles annealed seamless copper, aluminum, steel and stainless steel tubing. Can also be used for square-burring tubes in same size range. Powered by a 110-v ac $\frac{1}{3}$-hp motor, weighs approximately 168 lb. *Parker Appliance Co., Cleveland, O.*

Roller: Six hand-operated models have material capacity ranging from 16 to 24-gage sheet steel, forming width range of 12 to 42 in., and radius capacity from 2 in. to infinity. Feature is cam-idler, which permits forming of circles of any diameter in two passes through the rolls. Circles of the same diameter as the forming rolls or slightly larger can be formed in one

Waldes Truarc Ring Saves $2.84 Per Unit, Cuts Labor-Time and Materials in Hydraulic Packing Unit



OLD STYLE stuffing box required skilled worker to install packing rings one at a time, then adjust packing glands by trial and error. Disassembly was equally difficult, time-consuming and costly.

NEW Monopak Cartridge is smaller, lighter, streamlined and installed with one Truarc Retaining Ring. Disassembly and reassembly with new cartridge takes unskilled worker just 1 minute.

Hydraulic Accessories Company of Van Dyke, Michigan, uses a single Waldes Truarc Inverted Ring (internal series 5008) to hold Monopak Cartridge in cylinder head.

New design eliminates costly machining and saves 2⅛ lbs. of material. Re-design with Waldes Truarc Retaining Ring reduces stuffing box diameter from 3½″ to 2⅞″, and reduces length from 5⅞″ to 4⅜″. Allows savings in assembly, adjusting and testing.

NEW DESIGN USING WALDES TRUARC RING PERMITTED THESE SAVINGS PER UNIT

MACHINE TIME SAVED:	
Chucking, facing and boring	$ .72
Drilling and tapping 3 holes	.18
Drilling and counterboring 3 holes	.12
Assembling, adjusting, testing	.90
MATERIAL SAVED:	
1½ lbs. cast iron	.30
½ lb. bronze	.23
3 studs	.36
3 nuts	.03
TOTAL	**$2.84**

Waldes Truarc Retaining Rings are precision-engineered ... quick and easy to assemble and disassemble. Always circular to give a never-failing grip. They can be used over and over again. There's a Waldes Truarc Ring to answer every fastening problem.

Find out what Waldes Truarc Retaining Rings can do for you. Send your blueprints to Waldes Truarc engineers for individual attention, without obligation.

For precision internal grooving and undercutting ... Waldes Truarc Grooving Tool.

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TRUARC

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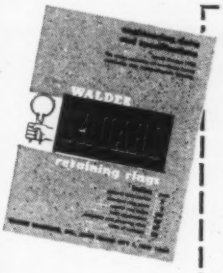
RETAINING RINGS

WALDES KOHINOOR, INC., LONG ISLAND CITY 1, NEW YORK

WALDES TRUARC RETAINING RINGS AND PLIERS ARE PROTECTED BY ONE OR MORE OF THE FOLLOWING U. S. PATENTS: 2,382,947; 2,382,948; 2,416,852; 2,420,921; 2,428,341; 2,439,785; 2,441,846; 2,455,165; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,509,081 AND OTHER PATENTS PENDING



Waldes Kohinoor, Inc., 47-16 Austel Place, L. I. C. 1, N. Y.

Please send me the new Waldes Truarc Retaining Ring catalog.
MD 105

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Compact, centralized construction incorporating selenium rectifiers and magnetic amplifier controls. One complete unit with static elements provides highly-efficient, maintenance-free, long-life, economical operation.

"Proof-tested" regulated battery chargers with completely automatic overload protection, maintain constant voltage output regardless of A.C. line variations or load fluctuations.

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A.C. INPUT: 110 or 220 volts, 50 or 60 cycles, single phase. Also 220 or 440 volts, 50 or 60 cycles, three phase.

D.C. OUTPUT: 3 to 60 cells in ratings to 50 Kw.

OUTPUT CONTROL: Automatic units float batteries at 2.15 volts and booster charge to 2.33 volts. Precise potentiometer adjustment on front panel.

VOLTAGE REGULATION: Less than ± 1% from no load to full load with ± 10% A.C. supply line variation.

Modern housings of heavy-gauge steel in panel, floor-standing or wall-mounted cabinets. Low installation cost... minimum space requirement.

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Upon Request

Write for complete engineering specifications.

INET INC.
8655 SOUTH MAIN STREET,
LOS ANGELES 3, CALIFORNIA

pass through the roller by making an adjustment. Bends can be located in any position along a sheet of material being formed in the roller; material can be fed through the rolls without bending until the cam lever is engaged. Thus, rectangles and other shapes with straight sections on both sides of the bend can be produced. Machines form round, flat and square stock. *O'Neil-Irwin Mfg. Co., Lake City, Minn.*

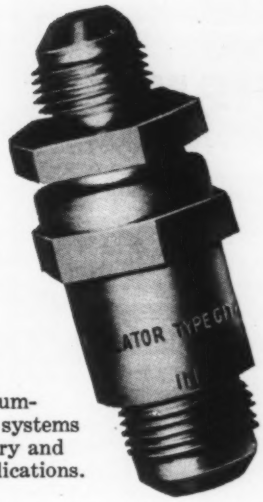
Vertical Milling Machine: No. 55, for high-speed milling and die sinking. Headstock swivels 90 degrees in either direction through a worm and worm wheel arrangement, enabling the head to be set accurately and swiftly to any desired angle; can be reset to zero rapidly. Working surface, 32 by 11 in., has a standard ¾-hp motor with eight speeds, 125 to 2960 rpm. Collet capacity is ⅝-in. *British Industries Corp., International Machinery Div., New York, N. Y.*

Punch Press: Redesigned 15-ton open back inclinable press offers continuous or single-stroke operation. Standard stroke is 2 in., with strokes available up to 4 in. Press is made in plain open belt with 125 strokes per minute and back geared with 70 strokes per minute. A metal guard completely covers the flywheel. Bed area is 8 by 15⅜ in. *Diamond Machine Tool Co., Los Angeles, Calif.*

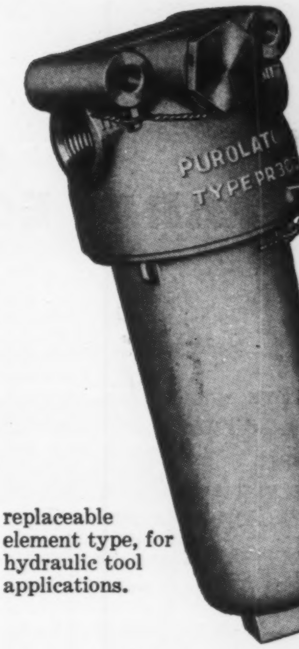
Drill Grinder: Bench Model DB has a capacity for ⅛ to 2½-in. drills and handles two, three and four-lip drills without any change in setup. No collets or jaws are required to hold the drills. Grinder has built-in diamond holder for accurate dressing of the wheel. *McDonough Mfg. Co., Eau Claire, Wis.*

Spot Welder: Type EB-3 produces a welding force of either 750 or 1000 lb maximum with 80 psi line pressure. Electrode stroke is 1¾ in. maximum. Lower horn is 2 in. diameter and vertically adjustable to 4 in., plus an additional 1¼ in. vertical adjustment when horn holder is inverted. Ejector type lower electrode holder is 6 in. long and 1 in. diameter, with a No. 1 Morse taper. Ejector type upper electrode holder is built as a per-

for high-
pressure systems.



for medium-
pressure systems
in military and
tool applications.



replaceable
element type, for
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applications.

PUROLATOR
TYPE G-2600M

for aircraft
hydraulic systems.

PUROLATOR
IN
OUT

for low-pressure,
high flow
systems.

When filter performance really counts...

specify **PurOlator**

FOR many years, Purolator* filters have been specified as standard equipment in hydraulic systems where failure might mean disaster . . . as in military and commercial aircraft.

Why not take a tip from the nation's leading plane designers, then—and specify Purolator filters in *all* hydraulic systems containing precision valves and actuators. Purolator hydraulic filters remove contaminants that are the most common cause of valve and piston failure—sludge, oxidation by-products, rust and metal particles.

And remember . . . whenever you specify Purolator, your choice is backed by the world's largest filter research and engineering laboratories, *plus* the world's largest specialized filter production facilities.

Send for the Purolator Industrial Filter Catalog, listing more than thirty different types, including A & N approved filters.

PUROLATOR PRODUCTS, INC., Rahway, New Jersey and Toronto, Ontario, Canada
Factory Branch Offices: Chicago, Detroit, Los Angeles

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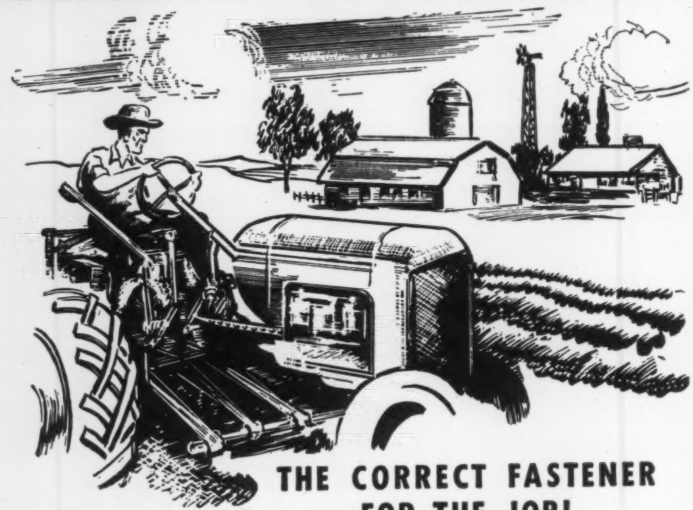
*Reg. U. S. Pat. Off.

For DEPENDABILITY IN FARM EQUIPMENT



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Precision and Quality Workmanship, backed up by 38 years of Erie experience, are yours for thoughtful buying. Whether you require a fastener made from carbon, alloy or stainless steels, to special design, to exacting specifications, Erie fasteners will save you time and expense . . . from your planning, to procurement, to fabrication. Submit your fastener requirements to us, Erie Service will meet the challenge.

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manent part of upper terminal and is for a No. 1 Morse taper electrode. Machine is small and compact; may be placed alone on a bench or in a bank or gang for production jobs. Throat depth is 8 in. *Taylor-Winfield Corp., Warren, O.*

Guillotine Punch: For production use or for taking test slugs during rolling operations. Provides 75 tons thrust and can punch a 1-in. hole through ¾-in. mild steel plate. Punch range is 13/16 to 1¾ in. Operating cycle requires 3 seconds per punch. Powered by a 2-hp electric hydraulic pump unit which can be foot-valve operated, the unit can also be boom mounted and swung into position for punching. *Manco Mfg. Co., Bradley, Ill.*

Pipe Threading Machine: No. 784 is a heavy-duty floor type machine with a standard range of 1 to 4 in. and an extra range of ½ and ¾-in. Equipped with a front chuck which does not require a wrench for operation, facilitating frequent changes of pipe sizes since handwheel moves gripping jaws through the entire range in a few seconds. Rear centering chuck together with extra long spindle provide maximum pipe support, prevent whipping and assure straight threads on long lengths. Machine has four spindle speeds. *Oster Mfg. Co., Cleveland, O.*

Plant Equipment

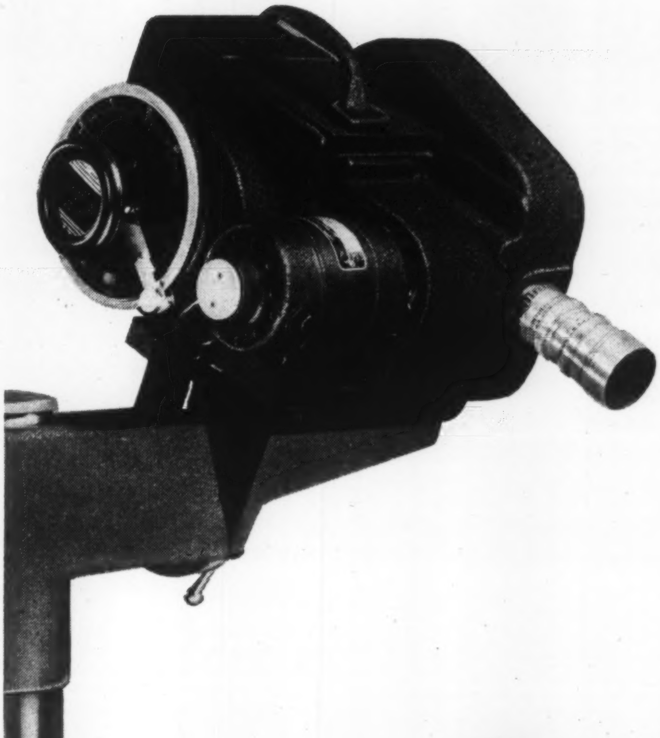
Pipe Bender: Type 2PBR bends ½ to 2-in. U. S. Standard pipe at radii approximately five times pipe size, up to 180 degrees. Minimum radius of bend it will handle is five times the pipe size; maximum radius of bend is 13 in. Will also handle bends up to 1½ in. extra and double extra heavy. Includes standard 2-hp motor and drum type reversing controller, as well as rollers and quadrants for the fixed radius bends available within capacity of the machine. *American Pipe Bending Machine Co., Poultney, Vt.*

Dust and Fume Eliminators: One unit is for wet collection and elimination only; another is a combination primary dry and secondary wet collection unit and has built-

Kodak

This camera helped speed production of PYREX casseroles

TRADEMARK PYREX ® MADE IN U.S.A.



The solution to production problems may sometimes be right in front of your eyes, yet can't be seen because the operation in question is moving at high speed.

Corning Glass Works' engineers had just such a problem in machining a new high-heat-conductivity alloy into dies that were expected to press molten glass into Pyrex casseroles faster and more economically. When trouble in machining this alloy made its use doubtful, it was decided to film the tool bit, as it operated at 246 r.p.m., with their Kodak High Speed Camera.

This camera takes motion pictures at speeds up to 3200 frames a second, slows motion as much as 200 times when the films are projected at normal speed. Study of their film showed Corning engineers that chips were sticking to one side of the tool bit, even though the tool was new. Further grinding was tried, and another study clearly showed the problem was solved. The special alloy *could* be properly machined, and the camera had helped show how.

Corning's high speed camera keeps busy finding answers to all sorts of problems involving mechanical action too fast for the eye to see.

A new booklet, "High Speed Motion Picture Making In Industry," is now available. It gives you complete details on the Kodak High Speed Camera, and shows how a number of industries have used this versatile instrument to solve difficult product design and performance problems. For your copy, write to:

Industrial Photographic Division
EASTMAN KODAK COMPANY, Rochester 4, N. Y.

the Kodak *HIGH SPEED* Camera

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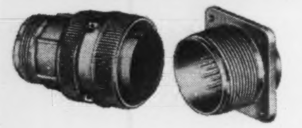
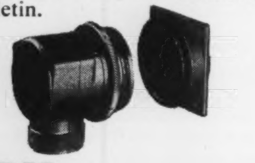
—widest use

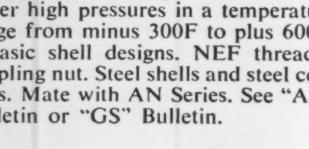


AN Designed to Air Force—Bureau of Aeronautics—requirements. Now widely used for all instruments requiring electrical circuits. Coupling nut connection and disconnection. Two plug types; 3 receptacles with variations and clamp accessories, in 15 shell sizes and more than 250 insert arrangements. A type for every need. Ask for "AN" Bulletin.

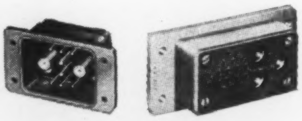


K & RK Designed for uses in aircraft, this versatile lightweight plug is widely used on a great variety of instruments and electronic equipment. Special acme coupling nut connection and disconnection. 8 contact sizes accommodate 16, 14, 10, 8, 6, 4, 2 and 0 AWG. Maximum 200a. 8 shell diameters. 204 insert variations. KH Series, hermetically sealed Type K, also available. Write for "K" Bulletin.

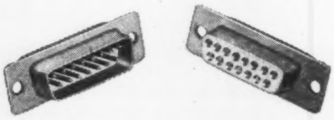
GS (AN) Designed for applications demanding hermetic sealing under high pressures in a temperature range from minus 300F to plus 600F. 2 basic shell designs. NEF threaded coupling nut. Steel shells and steel contacts. Mate with AN Series. See "AN" Bulletin or "GS" Bulletin.



XL For audio equipment and general electronic uses: 3 and 4 contact layouts, 10 and 15a; 17 shell designs; zinc and steel plug shells. Ask for "XL" Bulletin.

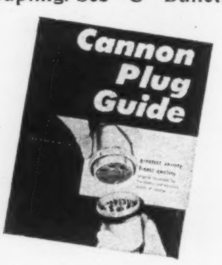


DPB-DPD For rack-and-panel installations, instrument panels and for any plug-in sub-assembly where both halves of the connector are rigidly mounted, or where one half is rigidly mounted and the other half cord mounted. 78 max. contacts, 200a maximum. Ask for "DP" Bulletin.



D SERIES SUB-MINIATURE PLUGS Designed to meet the miniaturization program. Used both as rack-and-panel disconnect and cord connectors for hand portable radio equipment, audio circuitry and related applications. Keystone shaped. 15 to 50 gold-plated contacts. DH hermetically sealed also available. See "D" Bulletin.

U SERIES SUB-MINIATURE PLUGS For hermetically sealed instruments, indicators, miniature switches, relays, transformers, amplifiers and other miniaturized sealed components. Steel shells & pin contacts; standard socket contacts in Silcan insulators. 1, 3, 6, 12 contact arrangements. 5a max. Bayonet lock coupling. See "U" Bulletin.



Send for a copy of the new Cannon Plug Guide.

CANNON ELECTRIC
Since 1915
CANNON ELECTRIC COMPANY, LOS ANGELES 31, CALIFORNIA
Factories in Los Angeles, Toronto, New Haven. • Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. J-185, Los Angeles 31, California.

New Machines

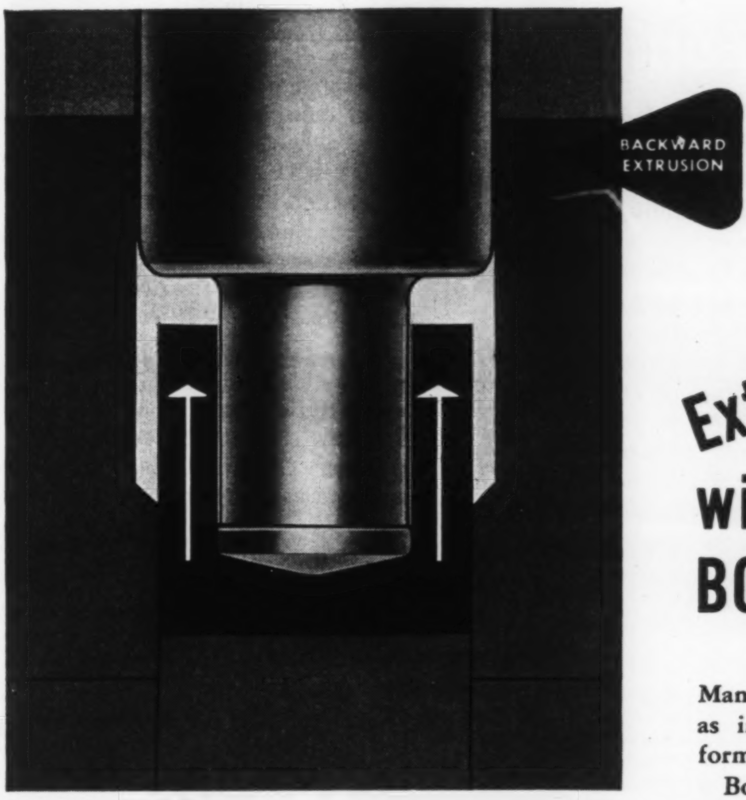
in precleaner for dry collection of heavier and most fine particles where material salvage is required. Both units combine cyclonic principle of dust separation and positive high-pressure water action to remove impurities from air in a rotating stream of water. For some applications, liquids other than water may be used. Features include low ratio of power to rated capacity, high ratio of water circulated to air volume handled, independently driven rotor and fan to permit adjustments to meet load and operating conditions, automatic liquid level control. *Schmieg Industries Inc., Detroit, Mich.*

Coolant Pump: For installation in the hollow column of a bench drill press. Driven by drill press motor, which is located above coolant supply, it eliminates danger of electrical shock. Circulates ½-gal of any type coolant through tubing beneath drill press. Extra heavy gage steel pan has side clips to hold splash shields when additional height is desired. Pump intake is screened to keep out drillings. *Wade and Sons, Independence, Mo.*

Power Plant Equipment

Electric Plants: Two models, designated HQ and rated at 10,000 and 15,000 w ac, are powered by gasoline engines. Provide electric power for both primary and standby applications. Features include impulse-coupled magneto with special radio shielding for easier and faster starting, sliding battery rack, 10½-qt cooling system, fuel consumption of less than 1 qt per kwhr at full rated load. Generator features voltage regulation of ±2 per cent and is direct connected to the engine by a semiflexible drive disk. Both models are available in all standard voltages, frequencies and phases, with or without housings. *D. W. Onan & Sons Inc., Minneapolis, Minn.*

Hydraulic Power Unit: Hydrau-Power-Pak is available in capacities from 5 to 50 gpm on the low-pressure side and from ½ to 6 gpm on the high-pressure side; pressure to 10,000 psi. Features Unitrol, which



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Bonderite and Bonderlube promote increased production, top quality and real economy.

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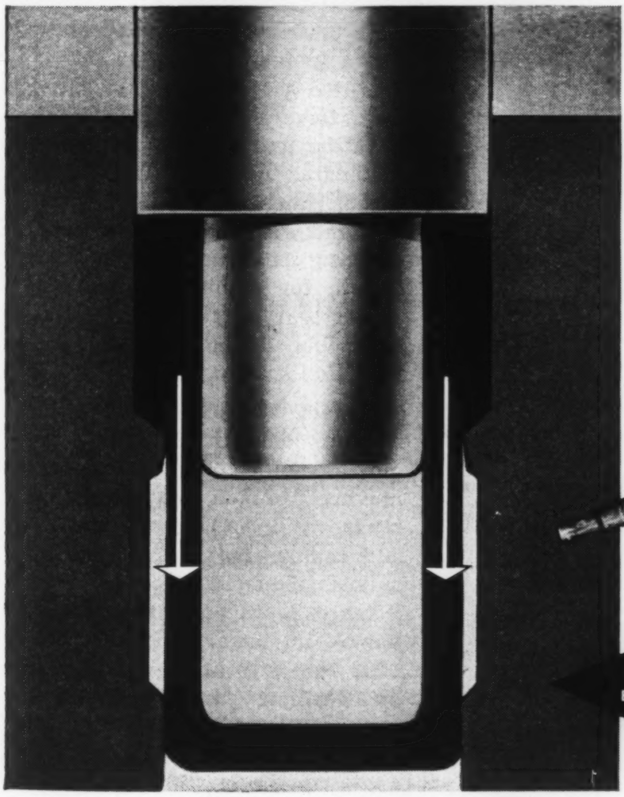

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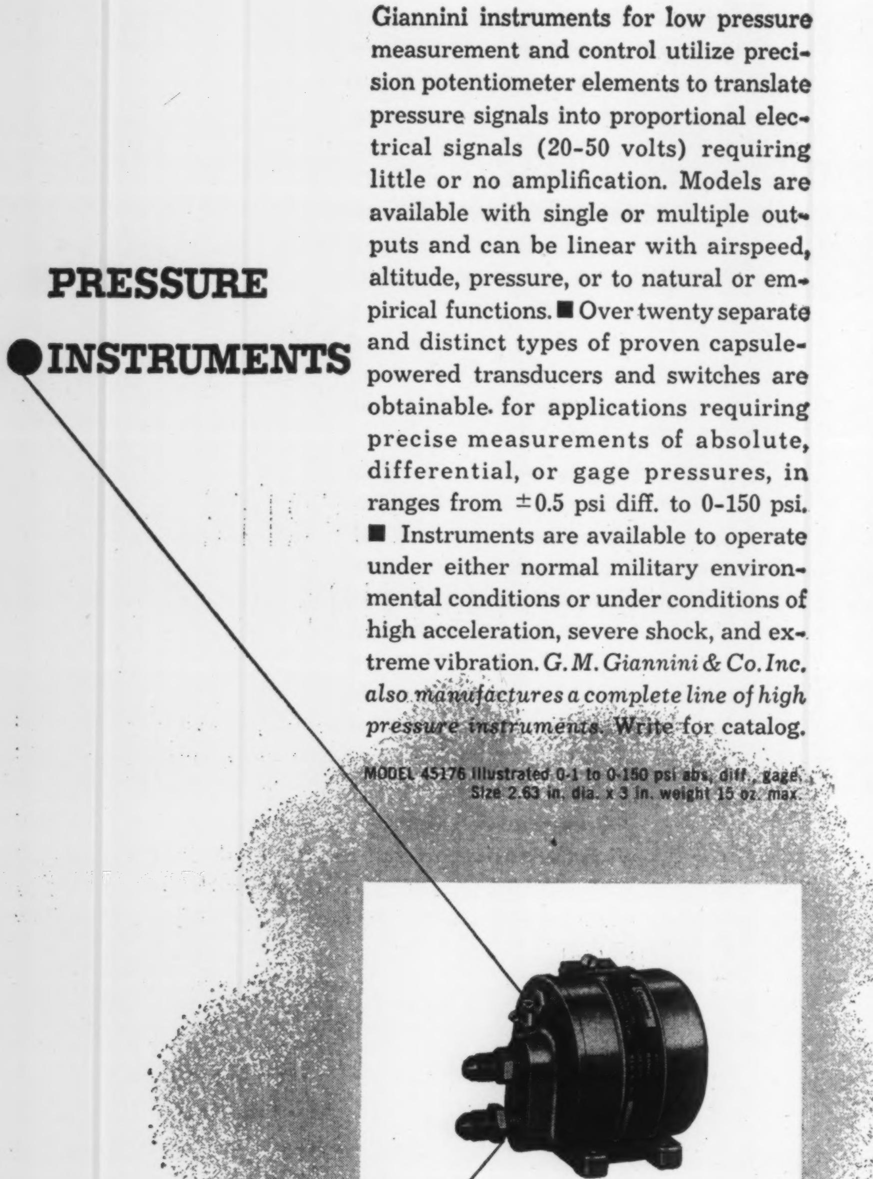
corrosion resistant paint base	aids in cold forming of metals	rust resistant	wear resistant for friction surfaces



PRESSURE
INSTRUMENTS

Giannini instruments for low pressure measurement and control utilize precision potentiometer elements to translate pressure signals into proportional electrical signals (20-50 volts) requiring little or no amplification. Models are available with single or multiple outputs and can be linear with airspeed, altitude, pressure, or to natural or empirical functions. ■ Over twenty separate and distinct types of proven capsule-powered transducers and switches are obtainable. for applications requiring precise measurements of absolute, differential, or gage pressures, in ranges from ±0.5 psi diff. to 0-150 psi. ■ Instruments are available to operate under either normal military environmental conditions or under conditions of high acceleration, severe shock, and extreme vibration. *G. M. Giannini & Co. Inc. also manufactures a complete line of high pressure instruments.* Write for catalog.

MODEL 45176 Illustrated 0-1 to 0-150 psi abs, diff., gage.
Size 2.63 in. dia. x 3 in. weight 15 oz. max.

MODEL 45177
Up to 4 outputs and inputs in ranges 0-1 to 0-150 psi abs, diff. or gage. (Set of 2 model 45176).

MODEL 45154
Ranges 0-5 to 0-30 psi abs. Size 2.25 in. dia. x 2.48 in. weight 8 oz. max.

MODEL 45172
Ranges 0-10 to 0-30 psi abs, diff. or gage. Size 2.19 in. x 2.83 in. weight 15 oz. max.

Giannini

G. M. GIANNINI & CO., INC. • PASADENA 15, CALIF. • EAST ORANGE, NEW JERSEY

eliminates piping, screwed connections, unnecessary valves and permits repair or replacement of valves with minimum down time and maintenance. Standard equipment includes relief valve, check valve, reservoir filter, air breather filter and dial. *Clifton Hydraulic Press Co., Clifton, N. J.*

Portable Tools

Mountable Hand Tool: Super 30 operates rotary tools for grinding, milling, finishing and polishing within a range of $\frac{3}{32}$ to $\frac{3}{16}$-in. shank diameter. Driven by 1/5-hp motor, spindle turns at 45,000 rpm; with speed control, rpm can be reduced in stages to 15,000. For precision internal grinding and milling with rotary tools, wheel arbors are available in $\frac{1}{8}$, $\frac{3}{16}$ and $\frac{1}{4}$-in. sizes. Has aluminum alloy housing; is air-cooled and vibrationless. Weighs 35 oz. *Precise Products Co., Racine, Wis.*

Screwdrivers, Nut Setters: No. 2 series includes 24 lightweight, air operated screwdrivers and nut setters. Reversible motors permit application and removal of threaded fasteners. Available in four basic speeds ranging from 475 to 2000 rpm and with either slip clutch, for exacting tension control, or positive clutch, for manual control. Lever or pistol type throttles available. Each tool weighs 2 lb. *Thor Power Tool Co., Aurora, Ill.*

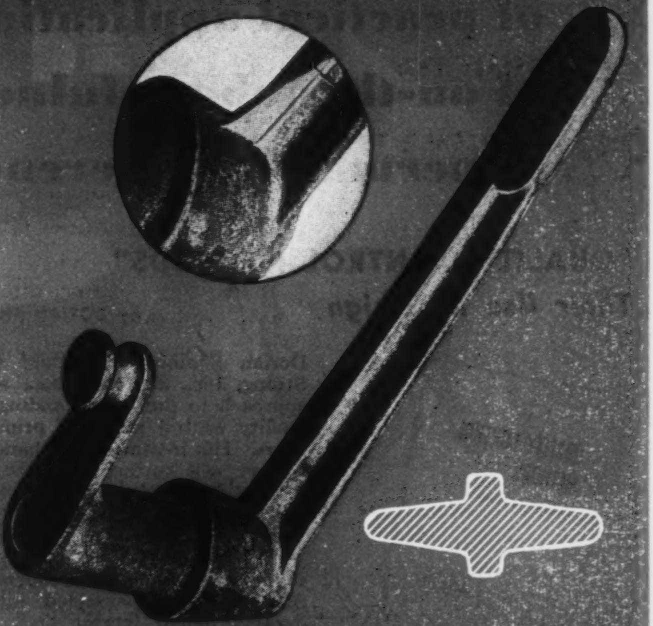
Impact Wrenches: Three pneumatic models for tightening or removing bolts and nuts and for removing broken capscrews and studs. Will tap, ream and drive and remove lag screws and screw spikes. "Squatty" Model PW-5014-S takes $\frac{7}{8}$-in. bolt or nut; spindle has $\frac{3}{4}$-in. square drive; speed is 1600 rpm free at 90 psi. Size $8\frac{1}{2}$ by $16\frac{3}{8}$ by $4\frac{1}{4}$ in.; weight, $19\frac{3}{4}$ lb. Model PW-4012P takes $\frac{3}{4}$-in. bolt or nut; spindle has $\frac{3}{4}$-in. square drive; speed is 1300 rpm free at 90 psi. Size, 11 by $7\frac{5}{8}$ by $3\frac{7}{8}$ in.; weight, 11 lb. Model PW-308P has capacity of $\frac{1}{2}$-in. bolt or nut; spindle has $\frac{1}{2}$-in. square drive; wrench has free speed of 1400 rpm at 90 psi. Size, 8 3/5 by 7 3/5 by $2\frac{3}{4}$ in.; weight, 6 lb. All have five-vane air motors, built-in automatic oilers

Case History M-121

Here's what we mean by SUPERIOR ENGINEERED FOUNDRY PRODUCTS...

PROBLEM:

Cracking was encountered in the production of this malleable iron casting (top photo). This condition required the foundry to use expensive and unreliable cracking strips. Rejects by foundry inspection were still in excess of 50%.

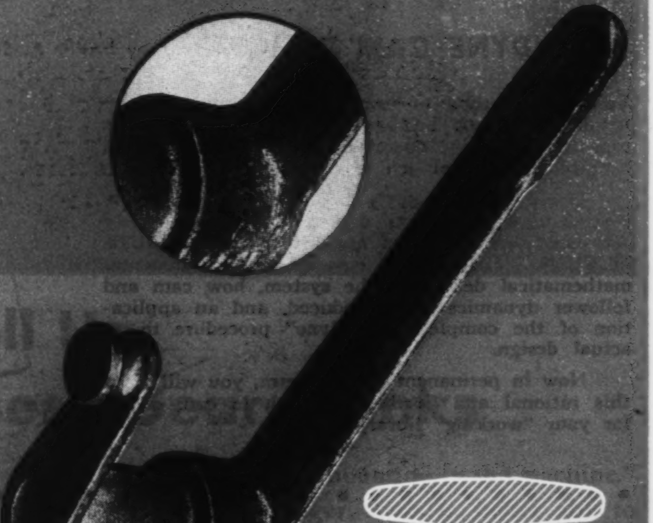


SOLUTION:

Application of a fundamental principle of SUPERIOR ENGINEERED FOUNDRY DESIGN—blend sections permit metal to solidify at a uniformly progressive rate through the casting, whereas abrupt changes from thin to thick sections impair the cooling rate and create stresses which break the casting.

RESULT:

Redesigned casting eliminated need for cracking strips. Rejects due to cracks were eliminated. 41.5% increase in strength without increasing weight. Deliveries speeded up, appearance improved.



Courtesy of Allis-Chalmers Manufacturing Co.

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It's here to help solve your design problems, save you time and money. *Superior* Engineered Foundry Design assures you maximum advantages of quality, cost, performance, machining, assembly, weight, appearance . . . any or all in a single product!

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Testing and Inspection

Spur Gear Tester: Floating head rests upon ultra-precision steel balls and contacts a dial gage reading in 0.0005-in. increments. Slide is held against gage by means of a spring which is adjustable to desired pressure. Scale and vernier reading in increments of 0.001-in. measures center distance. Gears to be tested are placed on fixed arbors or studs, thus avoiding rotating shafts which might introduce errors. Instrument reveals errors in center distance, eccentricity, spacing errors, presence of burrs, and aids in estimating backlash. *George Scherr Co. Inc., New York, N. Y.*

Air Height Gage: Airetest gives positive repeat readings when approached from front, back or sides. Indicator may be located where most convenient to operator, regardless of position of gaging stylus. Free from hysteresis; movement of a few millionths is instantly indicated. Instrument consists of a pickup arm mounted on a beam actuating an air jet connected to a 1000 to 1 or 2000 to 1 amplification gage; 5000 to 1 amplification is possible. Also used as a master testing device to determine flatness, parallelism, concentricity and other geometrical features of parts resting on a surface plate, clamped in required relation to a surface of a plate or rotated on precision centers or in V-blocks. Slender, can be used in holes, slots and grooves. Other possible uses include static strain gages, in dynamic strain gages with a recording unit, as center pickup unit in machine tools and as an indicator for various types of lead testers and gear checkers. *Sheffield Corp., Dayton, O.*

Balancing Machines: German made Schenck machines determine amount and location of dynamic and static unbalance in rotating parts. Models range in capacity from a few ounces to over 100 tons. Smallest pieces are balanced by adding or removing weight units at two of the four balancing points

Customers Tell Us Why They Like These Gear Blanks

Not long ago, we decided to investigate customer opinions of Bethlehem forged-and-rolled gear blanks. We asked some pretty direct questions, two of them being "Why do you specify Bethlehem gear blanks? What advantages have you found in these products?"

Here are a few of the answers:

☆ "Ease of machining and uniform finish allowance on OD, bore, and faces."

☆ "The solid, clean metal in the forged blanks is particularly appreciated in tooth-cutting operations on herringbone gear generators, gear shapers, or hobbing machines."

☆ "Fewer finishing cuts are required, and the cutting speed is usually higher."

☆ "There is almost never a rejection after cutting gear teeth."

☆ "The uniform finish allowance all over permits fast, uniform chucking or mounting in the machine."

☆ "The blanks are stronger, sounder, better able to withstand shocks."

The chances are, you would find Bethlehem forged-and-rolled blanks equally advantageous in meeting your own requirements. They are available in sizes from 10 to 42 in. OD, heat-treated or untreated, and are strongly recommended for spur, bevel, miter, and herringbone gears. Why not investigate? We feel that your own experience with these blanks will bear out fully what other users say about them.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

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HOT

specify

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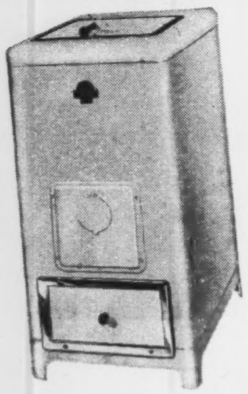
NEW IMPROVED SILICONE-BASE HEAT-RESISTANT FINISH

WITHSTANDS 500°–550°F in COLORS



SICON, in gleaming white, was chosen for this home incinerator because of its high resistance to heat, its exceptional color and gloss retention, and its adhesion and film stability. Sicon has revolutionized finishing wherever high temperatures pose a problem. Write for latest color application data.

Sicon

Silicone-Base Finish is manufactured exclusively by

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Waukegan, Illinois
ENAMELS · SYNTHETICS
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located within the co-ordinates, 90 degrees apart. Machines incorporate electrical measuring system, without electronic tubes or oscillograph, that indicates unbalances caused by displacements of as little as 0.00004-in. from center of gravity. Such measurements are indicated on a wattmeter which records only unbalance vibrations and is unaffected by disturbance vibrations of other frequencies. May be combined with machine tools to check, correct and inspect parts in one setup. *Cosa Corp., New York, N. Y.*

Temperature Test Chamber: Portable, self-contained Model TC-1 tests ambient temperature variations between −65 and 275 F. Can be equipped with a thermometer as an integral component. Forced circulation prevents significant temperature variations between thermometer and object on test tray. Cooling is accomplished with carbon dioxide ice; heating, by a high-capacity strip heater. Thermostatic control maintains temperature by balancing heat against dry ice evaporation. *Statham Development Corp., Los Angeles, Calif.*

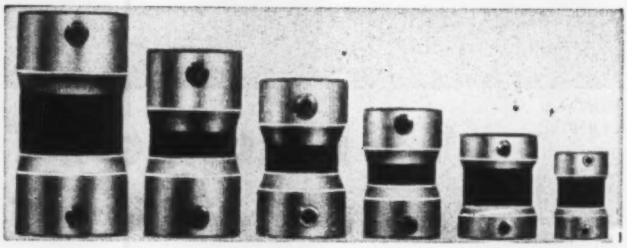
Altitude Test Chambers: Redesigned line simulates altitude conditions up to 100,000 ft. Available in 5 to 48 cu ft sizes. Operate in range between −70, −85 or −100 to 200 F. Provide humidity control between 20 and 95 per cent and pressure control from atmospheric to 8 mm mercury absolute, the equivalent of 100,000 ft. Multistage refrigeration system, vacuum pump and other operating machinery are vibration isolated from main frame and enclosed by removable panels. Control panel incorporates separate electronic, thermocouple type recording-controlling instruments for dry and wet bulb functions. Feature is high-volume, centrifugal air moving system within test space, proving increased heat transfer and temperature uniformity. Standard units are designed for a two to three-hour pull-down to extreme condition; modifications are available for more rapid temperature changes. *Hudson Bay Div., Refrigeration Systems Inc., Chicago, Ill.*

*Dyna-Line | FLEXIBLE COUPLINGS *TO FIT YOUR DRIVE!*

1/15 to 1-1/2 Horsepower →

Min. Length 1" to 2-3/8" →

Lengths to Your Drive Design Needs →



SPECIFY *Guardian* FOR BEST PERFORMANCE OF YOUR EQUIPMENT

* Exclusive Guardian Dyna-Line construction produces a superior one-piece flexible power connector by joining the three components into one unit while they are spinning and held in dynamic alignment.

In these couplings, the length of Flex-Element specified enters the function of needed adjustment to misalignment, or of added torsional damping. Exceptional lateral flexibility with minimum stresses imposed and torsional stability retained are controlled design features.

Exclusive manufacturers of Guardian Splined Sleeve Couplings—standard for years in the Oil Burner Industry. NOW AVAILABLE with long-wearing Nylon spline member. Ask about Guardian's NEW JAW-TYPE* coupling with Nylon member.

***Patent Pending**

Guardian Dyna-Line Couplings are available in "SUPER-CONSTRUCTION" in the #3 and #4 series which apply a quality factor of 2.0 to the H.P. ratings of these two series.

Write for

C-102 Catalog Page, also Drive Data Form #53 for coupling recommendations.

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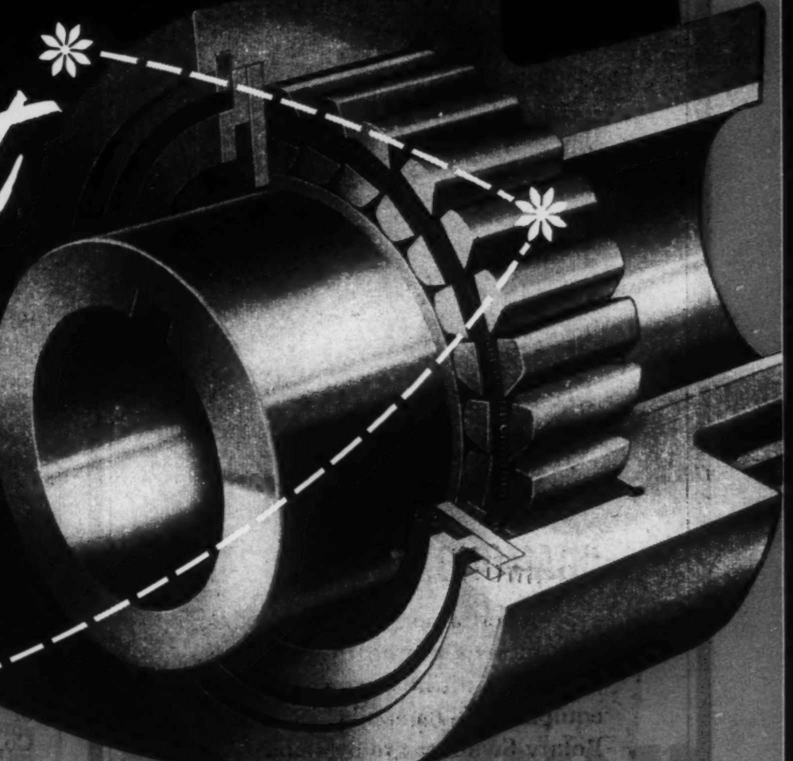
All FORMSPRAG CLUTCHES

ARE *Full Complement* CLUTCHES



WHAT IT MEANS:

A full complement of sprags is inserted in the annular space between an inner and outer race. Contact with race surfaces is maintained by energizing springs.

WHY IT'S IMPORTANT:

The energized sprags grip at an infinite number of positions. When torque is applied, the sprags *instantaneously* engage . . . when torque is removed, they *instantaneously* release. Positive, accurate engagement and disengagement may be made hundreds of times per minute—with no backlash.

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Proven performers in leading makes of window air conditioners, fans, blowers, unit heaters and similar equipment, "Diamond H" Series 240 Rotary Switches are available in 2, 3, 4 and 5 position models, with motor ratings and in a wide range of circuit variations and mounting arrangements.

Long, trouble-free service life and peak performance result from the "Diamond H" slow-break principle, heavy silver contacts, ingeniously simple design and rugged construction. Entirely enclosed for safety and protection of working parts. Conservative ratings (15 A., 125 V.; 7½ A., 250 V.; 1 h.p., 120 V.; 2 h.p., 240 V., A.C.) provide high overload capacity. UL Approved.

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118 Bartholomew Ave., Hartford, Conn.

MEN
OF MACHINES

Leo F. Spector

Leo F. Spector, assistant editor of MACHINE DESIGN since December 1951, has been promoted to associate editor. Mr. Spector received his B.S. in mechanical engineering from the University of Kansas. In Kansas City, he worked at the Marley Co. Inc. as a production engineer on research, development and design in connection with power transmission equipment and also assisted in the standardization, analysis and publication of engineering data. He is a member of the American Society of Mechanical Engineers.

◆

Robert L. Holloway has been named chief engineer of the Buffalo plant of American Machine & Foundry Co., New York. Associated with AMF for seven years, Mr. Holloway was formerly chief engineer of Eastman Machine Co. and also served in various engineering capacities at the airplane division of Curtiss Wright Corp.

◆

Formerly chief engineer of the Barberton, O., plant of Rockwell Mfg. Co., **Charles C. Reiff** has been promoted to chief engineer of the company's Delta Power Tool Div. at Bellefontaine, O. Mr. Reiff joined the company in 1950 as a design engineer with the Pittsburgh Equitable Meter Div.

◆

Robert G. Dobbin has joined the commercial motor section of Jack & Heintz Inc., Cleveland, as design engineer. For more than ten years he served as a designer of fractional-horsepower motors with the General Electric Co., and prior to joining Jack & Heintz was motor consultant for International General Electric at Schenectady, N. Y. and in Brazil.

◆

The appointment of **Clark Langworthy** as chief engineer for the industrial hydraulic products division was recently announced by the Parker Appliance Co., Cleveland. He will direct all engineering activity of the division, including production engineering and an extensive research and development program. Mr. Langworthy's background of experience in industrial hydraulics includes engineering positions with Standard Oil of Indiana and with Mead Corp. For the past 11 years he has been associated with Vickers Inc. in various engineering capacities. Most recently he was manager of a district office, directing design and installation of hydraulic systems and components.

◆

Clarence H. Linder

Clarence H. Linder, vice president and former general manager of General Electric's Major Appliance Div., has been appointed vice president of engineering. Mr. Linder, who received his B.S. and M.S. degrees in electrical engineering from the University of Texas, joined the company as a student engineer on the test course in 1924. He later completed the three-year advanced engineering program. Mr. Linder advanced to various positions and, in 1949, was named assistant to the general manager of the Apparatus department. He then served as manager of engineering of the company's former Affiliated Manufacturing Companies department and as general manager of the Major Appliance department. He was named vice president and general manager of the Major Appliance Div. in December 1952.

◆

The Engineering and Research Corp., Riverdale, Md., recently appointed **Gordon S. Light** as staff engineer to the president. Mr. Light joined the firm's engineering staff as a design engineer in 1946 and in 1951 assumed the duties of assistant chief engineer in charge of armaments.

◆

Oscar F. Haug has been appointed project engineer by Bendix Aviation Corp. for the Ultra-Viscoson, new ultrasonic instrument for measuring the viscosity of fluids. Formerly an engineer on the design and development of guided missile electronic components at the company's research laboratories in Detroit, Mr. Haug will be located at the Cincinnati division.

◆

Acme Steel Co., Chicago, has appointed **John H. Harper** chief staff engineer for its plant in Riverdale, Ill. He will be in charge of an additional engineering service for the management staff, which will include

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SOLVES MANY PROBLEMS
caused by sliding or rotating parts which are DIFFICULT OR IMPOSSIBLE TO LUBRICATE

A constantly increasing stream of problems are facing engineers and designers today involving sliding or rotating parts where lubrication is difficult or impossible. For such applications, Purebon, the mechanical carbon, is often the ideal answer. Typical applications are seal rings, bearings, pistons, piston rings, pump vanes, valve seats, meter discs, and a host of similar items. Purebon comes in a wide variety of grades. It is strong, tough, readily machinable and in many cases can be molded directly to size.

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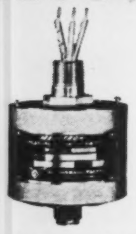
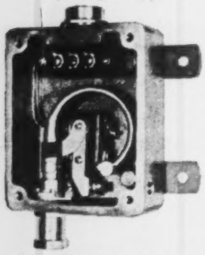
MELETRON
PRESSURE SWITCHES


diaphragm type


bourdon tube type

piston type

They operate in any position and are not affected by vibration. Explosion-proof models available.

Diaphragm type sensing elements for vacuum and low pressure (to 120 psi), bourdon tube type for high pressure (to 12,000 psi), and piston type for high cycling rate (to 15,000 psi).

Wherever a Vacuum or Pressure change must initiate electrical action there is a Meletron or Barksdale Pressure Switch to perform that function.

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BARKSDALE
VALVES
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preliminary surveys, layouts, analyses, estimates and proposals on major engineering projects. Mr. Harper joined Acme in 1948 and for the past four years has served as assistant chief engineer in the machine design engineering department.

◆

G. E. Burks

With responsibility for co-ordinating the program of all engineering groups serving the various plants and divisions of Caterpillar Tractor Co., Peoria, Ill., **G. E. Burks** is now director of engineering. Joining Western Harvester Co., then a Caterpillar subsidiary, as a designer and field engineer in 1928, Mr. Burks advanced through various drafting, design, research and supervisory positions. He was transferred to Peoria in 1938 as assistant chief engineer in charge of engine design and was named chief engineer in 1942. He is a member of the Society of Automotive Engineers, the American Society for Metals and the American Ordnance Association.

Other changes in engineering department personnel include the appointment of **John E. Jass** to succeed Mr. Burks as chief engineer of the Peoria plant, **Paul B. Benner** to the post of assistant chief engineer at the Peoria plant with supervision over design of motor graders and wheel tractors, and **Carl L. Kepner** to the post of assistant chief engineer with supervision of earthmoving equipment now manufactured at the Joliet plant.

◆

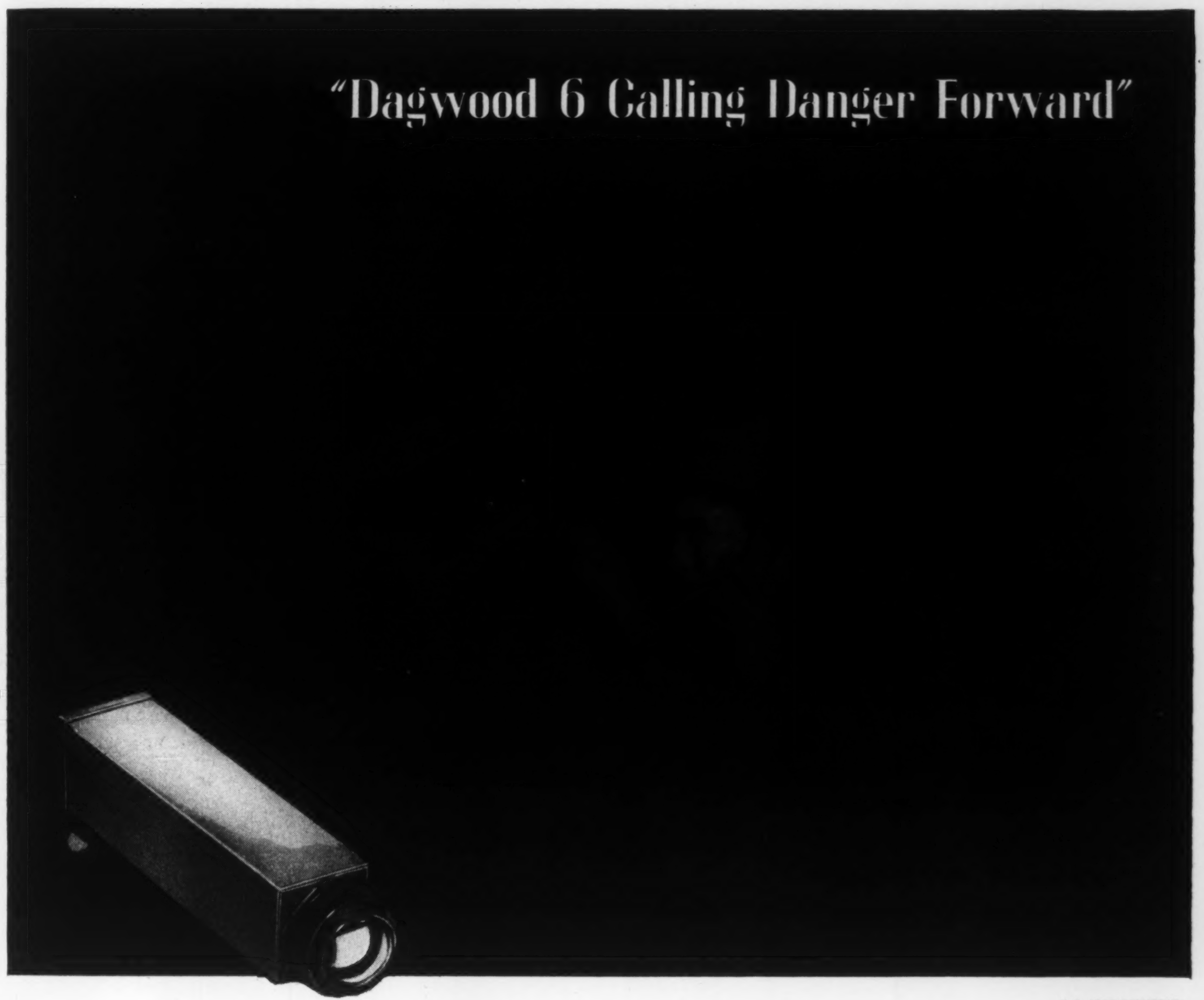
A. J. Jones, who joined the company 17 years ago as a college trainee, has been appointed chief engineer of Landis Tool Co., Waynesboro, Pa.

◆

Lipe-Rollway Corp., Syracuse, N. Y., has appointed **C. B. Spase** to the position of chief engineer of automotive development, with responsibility for all automotive research. Succeeding Mr. Spase as chief engineer of the clutch division, **Robert S. Root** will be in charge of heavy-duty clutch development.

◆

Frank R. Benedict has been appointed staff engineering manager on the staff of **H. E. Seim,** vice president and general manager of the Westinghouse Electric Co. Sturtevant Div. and Air Conditioning Div. at Hyde Park, Mass., and the Bryant Electric Co. of Bridgeport, Conn., a subsidiary of Westinghouse. Mr. Benedict, who joined the company in 1928, will oversee



"Dagwood 6 Calling Danger Forward"

U. S. ARMY PHOTOGRAPH

G.I. Joe now puts his calls through a new field switchboard twice the capacity and one-third the size of the one toted by his World War II counterpart.

The new "board" has a constitution that can winter in Rejkjavik, summer in Mombasa, and roll with a punch . . . just in case travel gets rough. Its retractable cords know when to come in out of the rain and goo.

Among the many essential parts of this instrument there is one named simply "SIGNAL, switchboard." It is a luminous-painted signal, operated by an electro-magnet, which "drops" into view when a line is calling. There's one "drop" for each telephone cord circuit; each drop is enclosed in a square housing made from Superior Hard Drawn Carbon Steel AISI C1008—.6815" I.D. Square, .020" wall, 2.656" long. Tolerances are close—±.005" on the length and +.007",—.000" on width.

Mr. Lloyd Bender, Vice President of The North Electric Manufacturing Company, makers of the switchboard, says of Superior, "Your performance has been excellent—in workmanship, quality of material and delivery."

Are you looking for a good small-tubing source—one that gives you the widest choice of tubing analyses available in America today, one that can supply you with one or one-million feet, one known for its uniformly high quality, and its interest in you and your tube problems? Try Superior. Superior Tube Company, 2010 Germantown Ave., Norristown, Pa.

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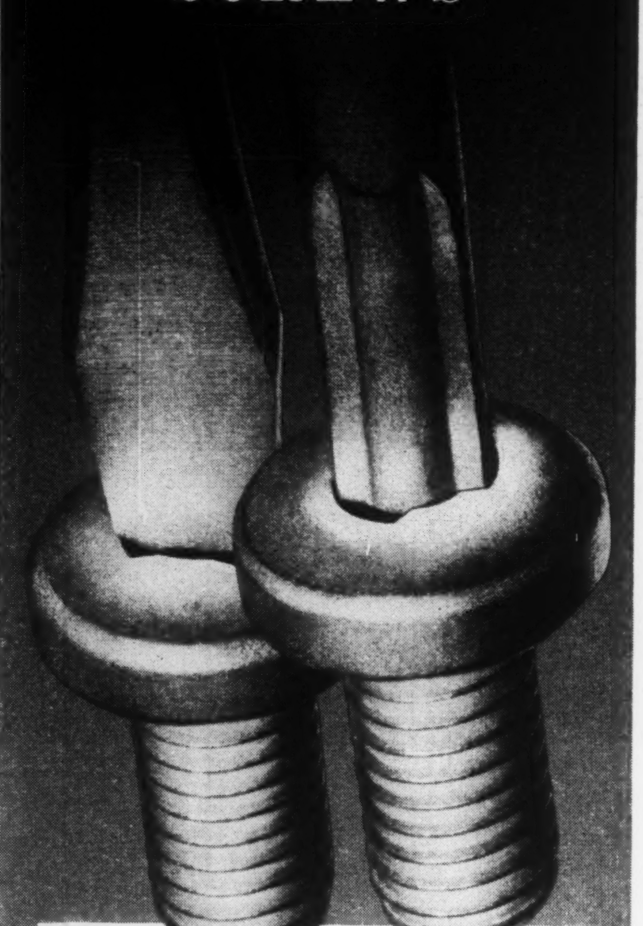

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and assist in the direction and co-ordination of the engineering and development of these divisions.

◆

Formerly head of the electronic controls division, **Charles Modersohn** has been named chief engineer of the industrial division of Warner Electric Brake & Clutch Co., Beloit, Wis. He will be responsible for the engineering of electric brakes and clutches for industrial machinery of all types. Mr. Modersohn joined Warner's engineering staff in 1951, after being with the Gardner Machine Co.

◆

Presently vice president of the American Society for Metals, **J. B. Austin** will be president of the society for the coming year. Mr. Austin is director of the research laboratories of U. S. Steel Corp., Kearney, N. J.

◆

Donald I. Bohn and **Louis N. Grier,** both of whom have been associated with Aluminum Co. of America, Pittsburgh, for over 30 years, recently were promoted by the company. Mr. Bohn, formerly chief electrical engineer, is now in charge of special electrical development engineering work. Mr. Grier, who was assistant chief electrical engineer, assumes the post of chief electrical engineer.

◆

Wilbur A. Lazier was recently named vice president and technical director in charge of research and engineering for Sprague Electric Co., North Adams, Mass. Dr. Lazier has served with the Du Pont Experimental Station, as first director of the Southern Research Institute and as director of chemical research and development for Chas. Pfizer & Co.

◆

James H. Wiegand, authority on double-base solid propellants for rockets and guided missiles, has joined the staff of the Southwest Research Institute.

◆

The new laboratory of the Trane Co., La Crosse, Wis., will have as its director **Donald H. Krans,** formerly professor in charge of the Heat Power laboratory of the University of Illinois. Under Mr. Krans' direction, the Trane laboratory will operate facilities for duplicating temperature, humidity, pressure and air movement conditions anywhere in the world.

◆

Formerly chief engineer, **A. B. Capron** has been named assistant works manager in charge of the tube mills and engineering for the Tubular Products Div. of Babcock & Wilcox Co., Beaver Falls, Pa.

◆

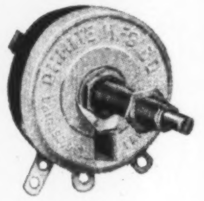
William J. Tell was recently promoted to the newly created position of staff engineer in charge of future body and sheet metal styling in the Cadillac Motor Car Div. of General Motors Corp., Detroit. He is succeeded by **Daniel M. Adams** as staff engineer for body and sheet metal design.

What Special Feature do you need in a RHEOSTAT?

OHMITE CAN SUPPLY IT!

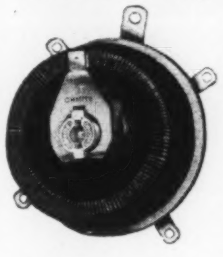
In addition to standard rheostats, Ohmite offers rheostats with a wide variety of *special features.* All have the distinctive Ohmite design features: smoothly gliding metal-graphite brush; all-ceramic construction; insulated shaft and mounting; windings permanently locked in place by vitreous enamel.

BUSHINGS FOR SPECIAL PANEL THICKNESS



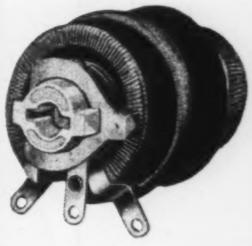
Extra-long bushings and shafts allow mounting on panels up to 2 inches in thickness. Seven bushing lengths are available, from ¼ to 2⅛ inches.

360° WINDING



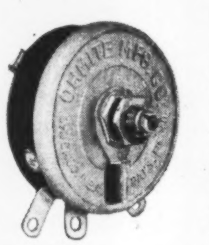
Two small models available with continuous circular core and endless winding. Unlimited rotation of shaft and contact arm. Taps supplied at any desired angle on windings.

DEAD LUG OFF POSITION



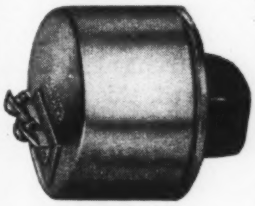
Opens the circuit at the high or low resistance position as the contact passes on to the lug, which is disconnected from the winding. Recommended for light duty.

SCREW DRIVER SLOT SHAFT



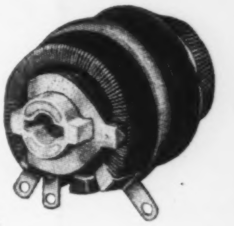
Where infrequent adjustments are needed, shaft ends can be slotted for operation with a screwdriver. Tampering with the shaft setting is thus minimized.

SEALED, ENCLOSED CAGES



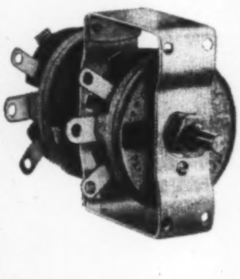
Compact, corrosion-resisting metal enclosure, permanently sealed by a double seam, protects the unit completely. Available with rheostat Models H and J.

SNAP-ACTION OFF POSITION



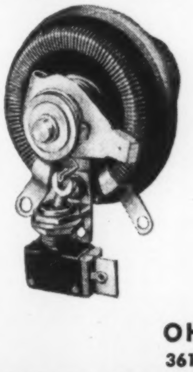
Opens the rheostat circuit at the high or low resistance position. The circuit is opened as the brush snaps into an insulated notch next to the lug, providing indexing.

TANDEM ASSEMBLIES



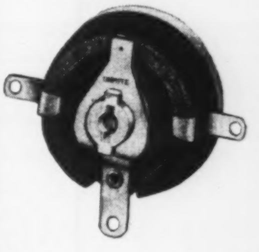
Ohmite rheostats can be mounted two or more in tandem, for simultaneous operation of several circuits. Universal joints provide smooth, positive mechanical action.

TOGGLE SWITCH



Toggle switch is operated with a positive snap by the movement of the contact arm. Opens the rheostat circuit or switches an independent circuit. Available for all models.

LESS THAN STANDARD ROTATION



Rheostats can be supplied with winding space and angle of rotation less than standard. Rheostats can also be supplied with fixed or adjustable stops.

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THE ENGINEER'S Library

Recent Books

Basic Mechanics of Fluids. *By Hunter Rouse, professor of fluid mechanics, and J. W. Howe, professor of mechanics and hydraulics, Iowa University,* 255 *pages,* 6 *by* 9 *inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, $4.50 *postpaid.*

Written as a guide for engineers and designers, this book deals specifically with the mechanics of fluids. Basic principles of kinematics and dynamics are applied to motion of a fluid in the first portion of the text, followed by a discussion of the effects of fluid properties. Elementary calculus is employed throughout along with illustrative material to explain fluid flow.

◆

Measurement Techniques in Mechanical Engineering. *By R. J. Sweeney, consulting engineer;* 319 *pages,* 6 *by* 9 *inches, clothbound; published by John Wiley & Sons Inc., available from* MACHINE DESIGN, $5.50 *postpaid.*

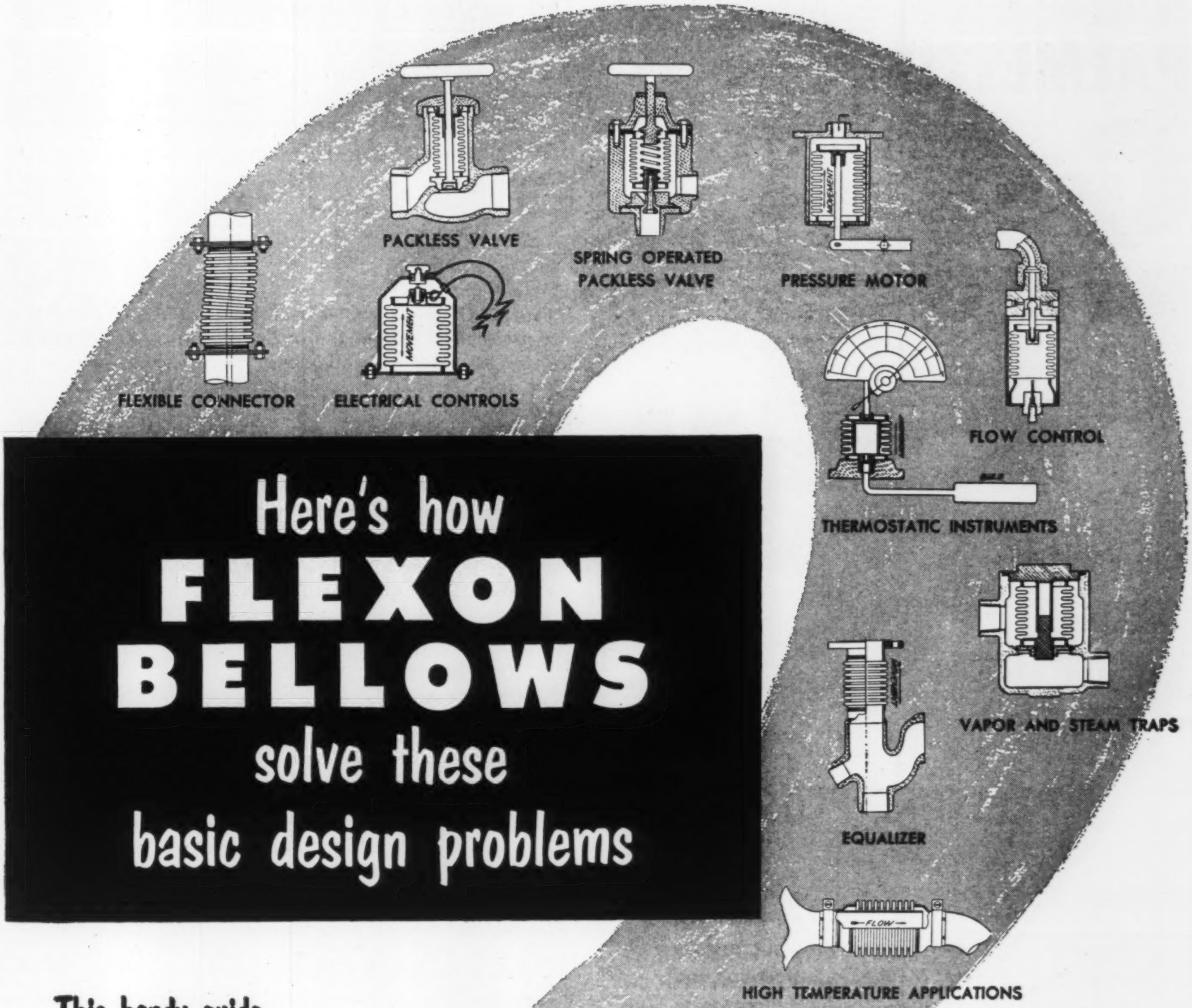
Providing an insight into the principles upon which instrument designs and measurement techniques are based, this book embraces the performance testing of power equipment—engines, pumps, compressors, and combustion and heat-transfer apparatus. Means and methods are described for measuring length, area, mass, density, time, speed, force, pressure, vacuum, temperature, humidity, fluid flow, calories, and electrical and chemical properties. The final chapter briefly discusses automatic controls.

◆

Radiotron Designer's Handbook. *Edited by F. Langford-Smith; Amalgamated Wireless Valve Co. Ltd., Sydney, Australia;* 1522 *pages,* 5½ *by* 8¾, *clothbound; reproduced by RCA Victor, Div. of Radio Corp. of America, Harrison, N. J.; available from* MACHINE DESIGN, $7.00 *postpaid.*

A fourth edition four times larger than the third, this handbook embraces the design of radio and audio circuits and discusses in detail, from the viewpoints of theory and practice, the design considerations necessary for the proper use of electron tubes and circuit components. Data concerning television, radio transmission, radar, industrial electronics, and test equipment have been excluded to limit the book's size. The material includes over 1000 illustrations along with bibliographies and references totaling more than 2500 items. A comprehensive 50-page in-

Here's how FLEXON BELLOWS solve these basic design problems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This handy guide will help you . . .

The Flexon Bellows Design Guide offers useful application data and basic specifications on Flexon brass and stainless steel bellows. If you do not already have a copy, write for yours today, or see Flexon Bellows specifications in Sweet's File for Product Designers.

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BELLOWS
BELLOWS ASSEMBLIES
BELLOWS DEVICES
Chicago Metal Hose Corporation

In any product that requires a motion controlled by temperature, or where a shaft or similar part must be sealed without packing, Flexon Bellows will answer the problem—and assure quality performance.

Flexon Bellows are manufactured by advanced methods to combine economy with exceptionally high standards of uniformity. They are available in brass, bronze or stainless steel in a complete range of sizes to meet virtually any need. For unusual applications, Flexonics bellows engineering specialists will be pleased to assist you. For quotations or recommendations, just send an outline of your requirements.

Flexonics Corporation

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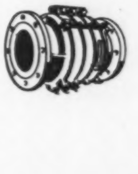
In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

Flexon identifies products of Flexonics Corporation that have served industry for over 50 years.

Flexible metal hose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Aircraft components

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In Taylor-Wilson's Automatic Hydraulic Pipe Testing Machine, the main packing problem was that of pressure. Non-extrusion at 3000 psi-water was the requirement. The G-T Ring was used successfully in a Youngstown Sheet & Tube Co. installation and in a pipe-tester later installed for the National Tube Co., a division of U. S. Steel Corporation. It has been "under pressure" for Taylor-Wilson ever since!

CANNOT EXTRUDE, *because*

As pressure is applied, conventional packings soon extrude into clearance space Y, then fail. Not so the G-T Ring! Because of its design consisting of a resilient sealing ring in a T-Section supported on each side by two non-extrusion rings, it cannot extrude. As pressure is applied to the G-T Ring, the resilient material flows under the non-extrusion rings, urging them against the cylinder wall and blocking the path of extrusion.

In pressure applications, dynamic or static—pick Palmetto G-T Ring—the packing **designed expressly for** non-extrusion.

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dex contains 7000 entries. The book is made up in seven parts: radio tubes; general theory and components; audio frequencies; radio frequencies; rectification, regulation, filtering and hum; complete receivers; and sundry data which include numerous tables, charts, and graphs.

◆

Top Management and Research. *By Philip R. Marvin, vice president, Commonwealth Engineering Co.; 128 pages, 5½ by 8½ inches, clothbound; published by Research Press Inc., Dayton, O.; available from* MACHINE DESIGN, *$5.00 postpaid.*

This book shows how research can be managed with definite objectives and profitable results within a reasonable time and at an acceptable cost. The first chapter points out that five research functions—basic research, product research, application advisory research, production process research, and production equipment research—contribute to supply new products and processes to a company. The chapters following discuss development of industrial research, management responsibilities, program evaluation criteria, and research contracting.

◆

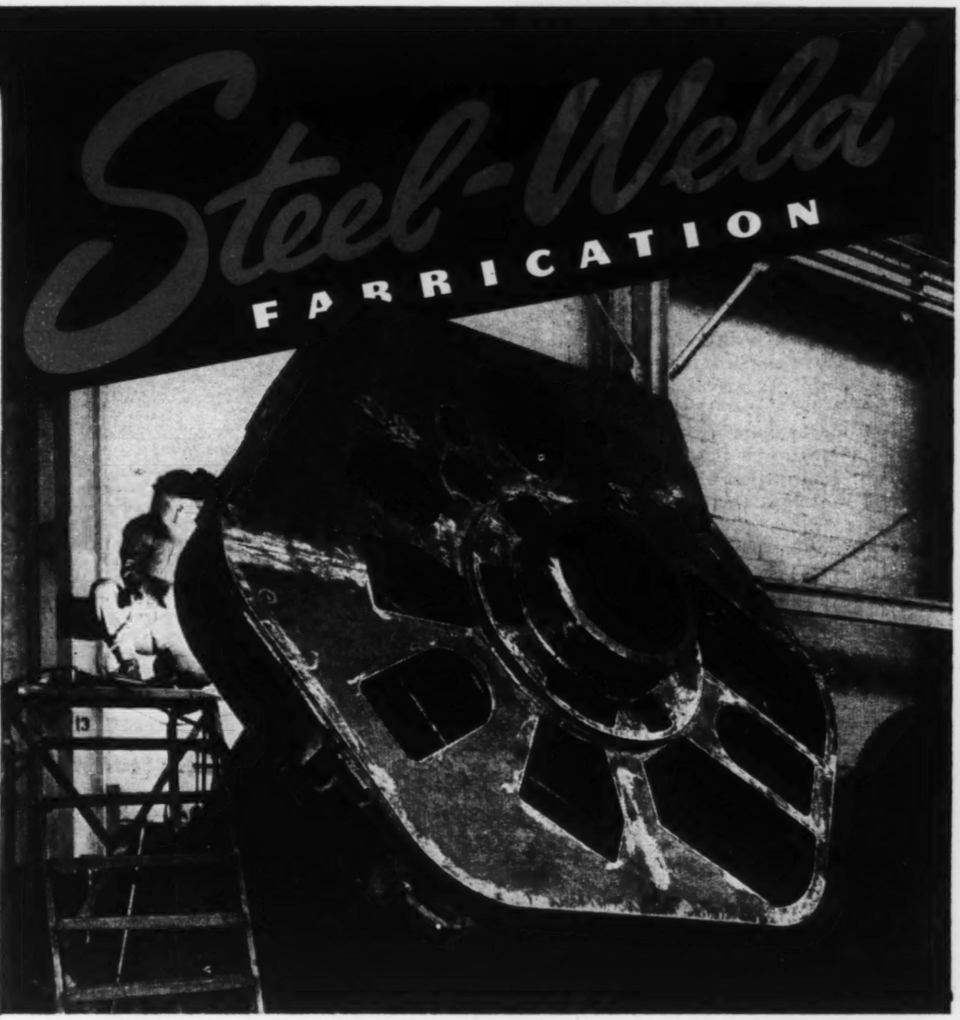
Applied Electricity. *By H. Cotton, professor of electrical engineering, Nottingham University, England; 494 pages. 5½ by 8½ inches, clothbound; published by the Industrial Press, New York; available from* MACHINE DESIGN, *$4.50 postpaid.*

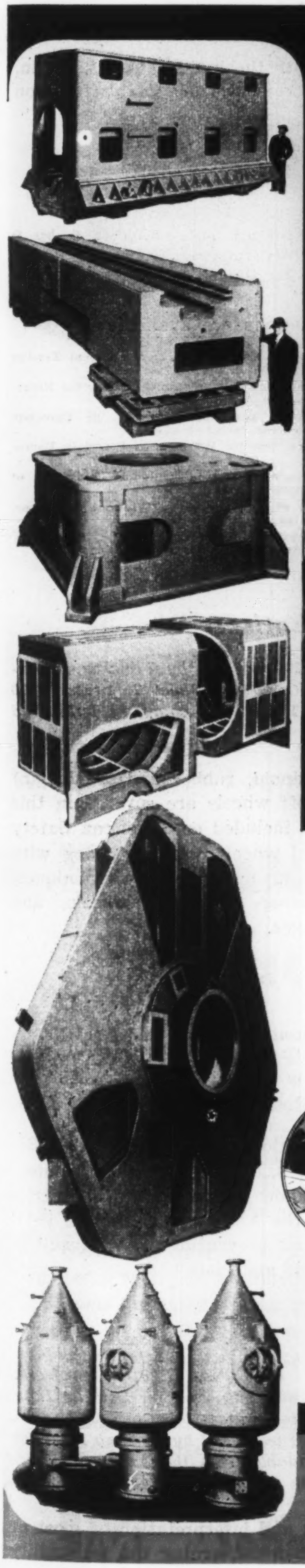
A second edition, this book covers the theory of magnetism, electrostatics, and electromagnetism along with the theoretical and practical aspects of all types of electrical equipment. Application of electrical theory to motors, generators, transformers, lighting devices, electronic equipment, and measuring instruments make up the bulk of the contents. Basic equations and solved example problems are dispersed throughout the text.

◆

Textbook of the Materials of Engineering. *By Herbert F. Moore, professor of engineering materials, University of Illinois, and Mark B. Moore, associate professor of mechanical engineering, Rutgers University; 382 pages, 6 by 9 inches; published by McGraw-Hill Book Co. Inc., New York; available from* MACHINE DESIGN, *$6.00 postpaid.*

This is the eighth edition of a book which was originally published in 1917. Concisely presented are the properties of various materials employed in machine and structural parts which affect the strength, stiffness, ductility, and resistance to corrosion or wear. Coverage of these properties includes methods of production such as casting, molding, etc., and methods of strengthening materials such as heat treating, alloying, hammering, rolling, and aging. Effectiveness of various treatments for structural or machine





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Illustrated here you see a few typical examples of thousands of Steel-Weld Fabricated parts and assemblies produced and machined by Mahon for hundreds of manufacturers of heavy machines and other mechanical equipment. If parts of your product could be redesigned and produced to better advantage through Steel-Weld Fabrication, or, if you require a limited number of large heavy pieces, in which pattern costs are a consideration, you can turn to Mahon with complete confidence . . . personnel and facilities are available within the Mahon plant to do the complete job from drawing board to finished machining. You will find in the Mahon organization a unique source with complete ultramodern fabricating, machining and handling facilities to cope with any type of work regardless of size or weight . . . a source where skillful designing and advanced fabricating technique are supplemented by craftsmanship which assures a smoother, finer appearing job embodying every advantage of Steel-Weld Fabrication. See Mahon's Insert in Sweet's Product Design File, or write for further information.

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DETROIT 34, MICHIGAN

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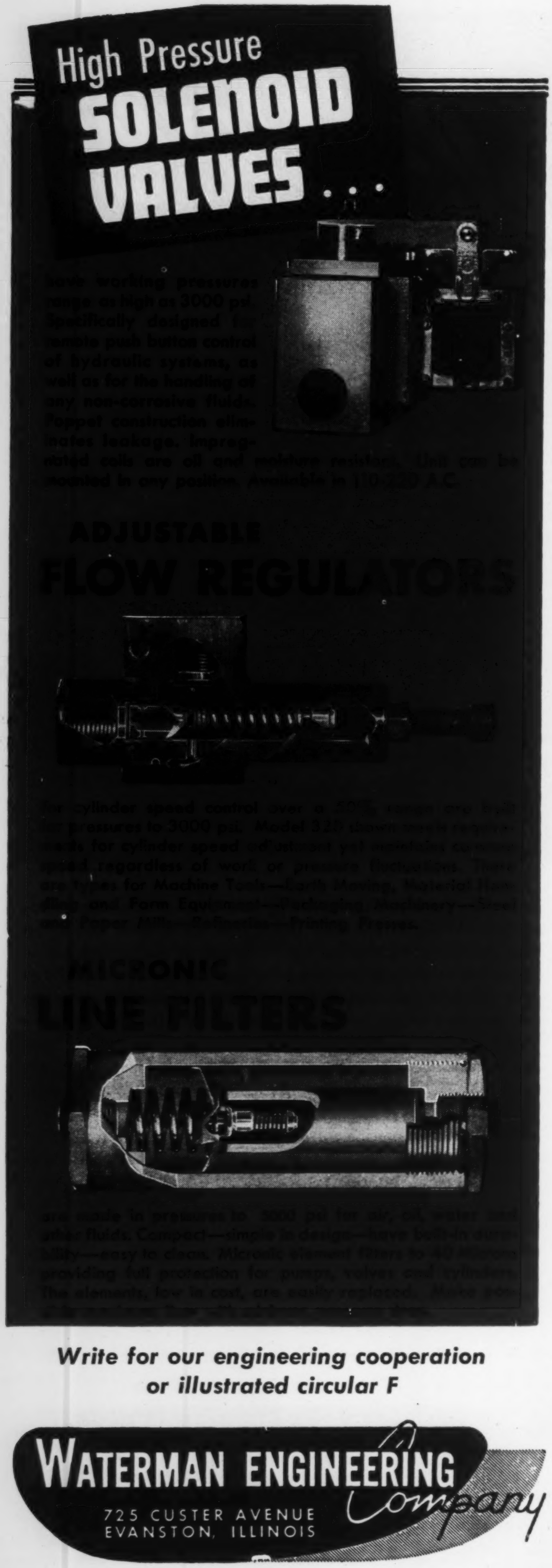
High Pressure
SOLENOID
VALVES . . .

have working pressures range as high as 3000 psi. Specifically designed for remote push button control of hydraulic systems, as well as for the handling of any non-corrosive fluids. Poppet construction eliminates leakage. Impregnated coils are oil and moisture resistant. Unit can be mounted in any position. Available in 110-220 A.C.

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for cylinder speed control over a 50% range are built for pressures to 3000 psi. Model 320 shown meets requirements for cylinder speed adjustment yet maintains constant speed regardless of work or pressure fluctuations. There are types for Machine Tools—Earth Moving, Material Handling and Farm Equipment—Packaging Machinery—Steel and Paper Mills—Refineries—Printing Presses.

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are made in pressures to 3000 psi for air, oil, water and other fluids. Compact—simple in design—have built-in durability—easy to clean. Micronic element filters to 40 Microns providing full protection for pumps, valves and cylinders. The elements, low in cost, are easily replaced. Make [illegible]

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EVANSTON, ILLINOIS

parts is shown along with the limiting stress, strain, or strain energy under which various metals function satisfactorily.

New Standards

1953 ASTM Standards. *Each publication is 6 by 9 inches; copies available from American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.*

The following publications are available:

A370-53T. **Tentative Methods and Definitions for Mechanical Testing of Steel Products**—27 pages.

B282-53T. **Tentative Specifications for Sintered Metal Powder Structural Parts from Brass**—4 pages.

C313-53T. **Tentative Method of Test for Adherence of Porcelain Enamel and Ceramic Coatings to Sheet Metal**—9 pages.

C314-53T. **Tentative Method of Test for Warpage of Porcelain Enameled Flatware**—6 pages.

D1263-53T. **Tentative Method of Test for Leakage Tendencies of Automotive Wheel Bearing Greases**—4 pages.

D1264-53T. **Tentative Method of Test for Water Washout Characteristics of Lubricating Greases**—3 pages.

D1277-53T. **Tentative Specifications for Nonrigid Thermoplastic Compounds for Automotive and Aeronautical Applications**—3 pages.

Association Publications

Cutting-Off Wheels. 20 *pages,* 5 *by* 7 *inches, paperbound; available from Grinding Wheel Institute,* 2130 *Keith Bldg., Cleveland* 15, *O., on company letterhead request.*

Organic bonded (resinoid, rubber and/or shellac) solid straight cutting-off wheels are covered in this booklet. Information is included on American Safety Code wheel speeds and wheel mounting along with data concerning work supporting, cutting techniques, types of machines using cutting-off wheels, and causes of wheel breakages.

◆

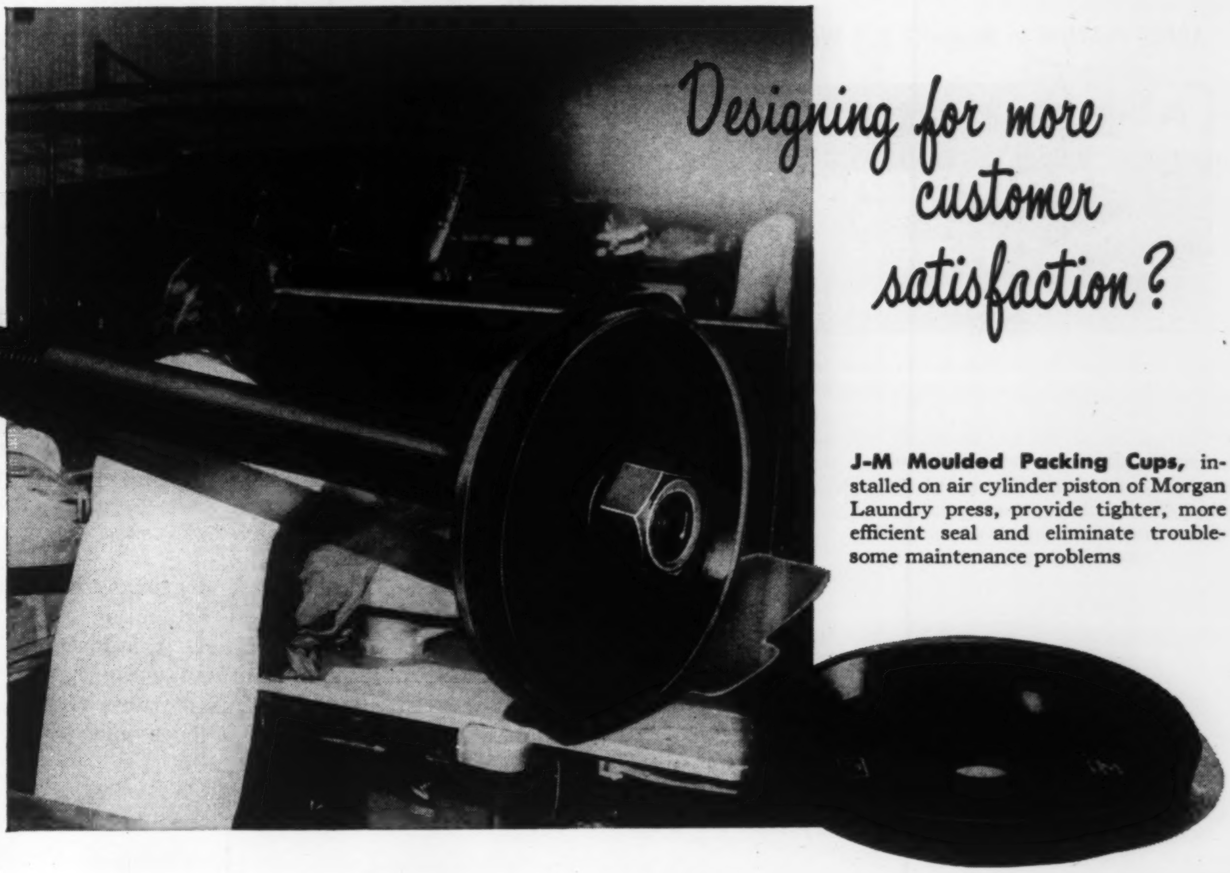
The Organizational Position of the Industrial Safety Engineer. 30 *pages,* 5½ *by* 7½ *inches, paperbound; available from the Society for Advancement of Management,* 74 *Fifth Ave., New York* 11, *N. Y.,* $1.00 *per copy.*

Published in co-operation with the American Society of Safety Engineers, this booklet consists mostly of 17 charts which show the progress of industrial safety programs since the ASSE was formed in 1911. It is shown that accident prevention efforts result in savings in manpower and materials.

◆

Weldability of Steels. *By Robert D. Stout, professor of metallurgy, Lehigh University, and W. Dorville Dotz, welding metallurgist, United States Steel Corp.;* 393 *pages,* 6 *by* 9 *inches, clothbound; published by Welding Research Council, New York; available from the American Welding Society,* 33 *West* 39*th St, New York* 18, *N. Y.,* $6.50.

An over-all analysis and interpretation of most of the available information concerning the weldability



J-M Moulded Packing Cups, installed on air cylinder piston of Morgan Laundry press, provide tighter, more efficient seal and eliminate troublesome maintenance problems

When Morgan Laundry changed to J-M Moulded Packing Cups, they found·

"Maintenance on packings practically eliminated..."

The Morgan Laundry, large supplier to hotels and institutions, encountered excessive down time for maintenance of their laundry presses. Packings supplied as original equipment on the air cylinder pistons of the presses needed frequent lubrication to prevent drying out. It was difficult to maintain proper cleanliness of the equipment.

When the company replaced the conventional material with J-M Moulded Packing Cups, packing life was increased. These packings required practically no maintenance, and the danger of soiling laundry because of relubricating packings was completely eliminated.

Designers and manufacturers can offer their customers many advantages by providing J-M Moulded Packing Cups on original equipment. These custom-made materials may be used on practically all types of air- or hydraulic-operated cylinders. They help improve operating efficiency, and they make possible easier, cleaner maintenance. These factors are especially important in critical installations such as hospitals and hotels, as well as laundries and other service establishments.

J-M Moulded Packing Cups are available in a variety of compositions to meet a wide range of pressures, temperatures and service conditions. For more information on all types of Johns-Manville Moulded Packing Cups, write to Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

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ASCO

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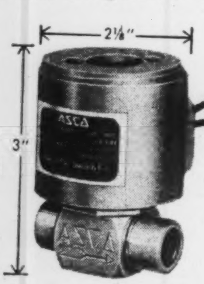
protection for

Personnel, Production & Plant

ASCO Midget Valves are now available with explosion-proof housings, designed in accordance with Underwriters' recommendations for use in Class 1, Group D hazardous locations. These Bulletins 8262 & 8314 ASCO Valves with the Explosion-Proof Solenoid Enclosure (they're also water tight) may be just what you need. Classed as "small" valves, they are doing a big job in the automatic and remote control of air, gas, water, light oils, refrigeration and other fluids.



Bulletin 8262 Two-Way ASCO Solenoid Valves (Illustrated) can be obtained with by-pass and metering devices. Valves can be installed in any position. Bulletin 8314 Three-Way Valves can be applied to any 3-way valving requirement regardless of flow directions or pressure application points; no change of springs or other adjustments are necessary. These valves can also be mounted in any position and will give positive tight shut-off.

BULLETIN 8262

2-Way Valve (Normally Closed)**

(Available for all commercial and industrial voltages)

Body Material		Brass or Stainless Steel			
Pipe Sizes (inches)		1/8		1/4	
Orifice Diameters (inches)		1/16	1/8	5/32	3/16
Maximum Pressures lbs./sq. in.	A-C	300*	130	90	60
	D-C	250	70	50	30

*Available 1000 psi in stainless steel; 500 psi in brass.
**Also available normally opened.

BULLETIN 8314

3-Way Valve

(Available for all commercial and industrial voltages)

Body Material		Brass or Stainless Steel	
Pipe Size (inches)		1/8	
Orifice Diameters (inches)		3/64	3/32
Maximum Pressures lbs./sq. in.	A-C	125	45*
	D-C	50	25*

*Pressures slightly lower for liquids.

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Write for free pamphlet "Small Solenoid Valves."

ASCO Solenoid VALVES

Automatic Switch Co.

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of carbon and low-alloy steels is made in this monagraph. Early chapters of the book briefly discuss weldability without reference to welding processes and metallurgy. Basic factors which influence weldability of carbon and low-alloy steels are presented after which suggested methods are given for welding commonly used steels. Remaining chapters contain a review and critical evaluation of weldability tests and present-day knowledge of weldability.

Manufacturers' Publications

RCA Tube Picture Book. 16 *pages,* 8½ *by* 11 *inches, paper cover; available from Radio Corporation of America, Tube Dept., Harrison, N. J.,* 25 *cents.*

Photographs, cutaway drawings, and exploded views showing structural details of electron tubes employed in home entertainment, industrial, and military electronic equipment make up the contents of this booklet. Typical types of tubes from miniature sizes up through power triodes and television picture tubes are included.

◆

Weld Standards. 19 *sheets,* 8½ *by* 11 *inches, paperbound; available from Lincoln Electric Co.,* 22801 *St. Clair Ave., Cleveland* 17, *O.,* $1.00 *in U.S.A.,* $1.50 *elsewhere.*

For a specified plate thickness, *Weld Standards* gives electrode type and size, polarity and current, electrode melt-off rate, arc speed, number of passes or beads, feet of joint welded per hour, and pounds of electrode required per foot of weld. All these factors are specified by employing the weld standard designation in conjunction with the regular American Welding Society symbols. This material covers manual of welding of butt welds, fillet welds, lap and corner weld in all positions in both plate and sheet metal.

Government Publications

NACA Technical Series. *Each publication is* 8 *by* 10½ *inches, paperbound, side-stapled; copies available from National Advisory Committee for Aeronautics,* 1924 *F St. N. W., Washington* 25, *D. C.*

The following Technical Notes are available:

2933. **Behavior of Materials under Conditions of Thermal Stress**—105 pages.

2987. **Charts Relating the Compressive Buckling Stress of Longitudinally Supported Plates to the Effective Deflectional and Rotational Stiffness of the Supports**—53 pages.

2988. **Temperatures, Thermal Stress, and Shock in Heat-Generating Plates of Constant Conductivity and of Conductivity that Varies Linearly with Temperature**—62 pages.

2993. **Calibration of Strain-Gage Installations in Aircraft Structures for the Measurement of Flight Loads**—40 pages.

2994. **Column Strength of H-Section and Square Tubes in Postbuckling Range of Component Plates**—106 pages.

2999. **Impingement of Droplets in 90-Degree Elbows with Potential Flow**—58 pages.

3001. **Comparison of Operating Characteristics of Four Experimental and Two Conventional 75-Millimeter Bore Cylindrical-Roller Bearings at High Speeds**—27 pages.

STANDS W R... AR...HEAT

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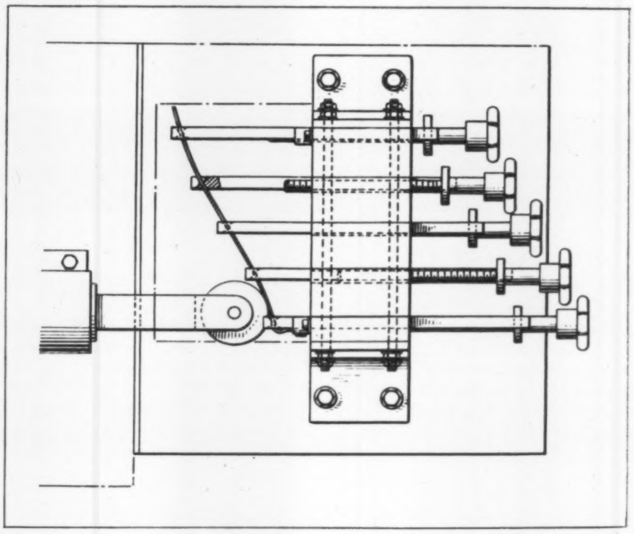
NOTEWORTHY Patents

VARIABLE CAM CONTOUR permits accurate adjustment of profile to conform to predetermined patterns and offers flexibility in machine performance. Detailed in patent 2,633,036 and assigned to Glenn L. Martin Co. by Mahlon A. Winter, the cam surface is formed by a flexible metal contour strip which guides the follower and is positioned by a series of interchangeable and adjustable slides mounted on blocks and stacked between two endplates. Degree of projection of the separate slides governs the profile shape and is controlled by individual handwheels through threaded rods. Cam length, a function of the number of slide units, can readily be varied to suit a particular range of movement. Secure assembly of the slides is accomplished by tiebolts. Designed primarily for use with pressure forming equipment, the cam facilitates service adjustments and simplifies assembly and maintenance problems encountered.



HIGH SHOCK RESISTANCE is obtained with "bouncing" putty in a unique rotary shock absorber assigned to General Electric Co. Designed by Robert W. Dunham, the device described in patent 2,631,690 employs two concentric cylinders separated by a filler of silicone putty; the inner cylinder is free to rotate and is connected to the working member. Under gradual movement, only negligible restraint is exerted by the putty. However, when subjected to sudden shock loads the putty acts like an elastic solid with high shear resistance, sharply limiting the motion of the cylinder and the working member. Designed for use

G.P.&F. Produces 1,000,000th Ammunition Box

The Sheboygan, Wis., plant of Geuder, Paeschke & Frey Co., recently celebrated the completion of the one-millionth .30-cal. ammunition box it is now producing for the government. Shown in the photo above are, left to right: William Livingston, Assistant Chief of Purchasing, Chicago Ordnance District; Frank T. Frey, G. P. & F Executive Vice-President; Major E. A. Smith, personal representative of Colonel Haskell, Commanding Officer, Chicago Ordnance District; August K. Paeschke, G. P. & F. President; Major R. E. Ryan, Commanding Officer Milwaukee Regional Office, Chicago Ordnance District. G. P. & F.'s Sheboygan branch plant is devoted entirely to military production.

● Whether your requirements are for military use or civilian use—whether you need an ammunition box or a washing machine tub—if it's stamped or drawn, chances are that G. P. & F. can do it for you. When you think of G. P. & F., think of over 1000 skilled people . . . 15 acres of production facilities . . . 293 deep draw and stamping presses . . . 97 welding machines . . . a complete tool and die department.

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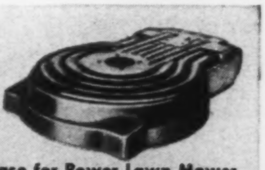
Automobile Oil Pan
Hot Dip Lead Coated

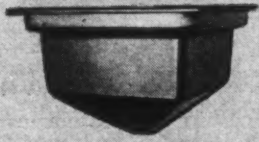
Washing Machine Tub
Seamless Drawn—
Vitreous Enameled

Radio Case
U. S. Signal Corps

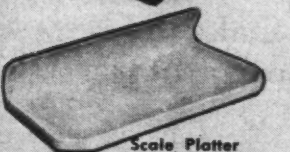


Base for Power Lawn Mower
Seamless Drawn Steel

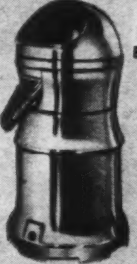
Aerial Delivery Container
U. S. Air Force



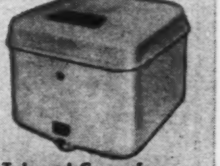
Deep Fat Fryer Pot
Stainless and Carbon Steel



Scale Platter
Vitreous Enameled



Commercial Fruit Juicer
Stainless Steel



Tub and Cover for Portable Dishwasher
Seamless Drawn Aluminum—
Baked Enamel Finish

G.P.&F.

STAMPING • DRAWING • FORMING
WELDING • SPRAY FINISHING
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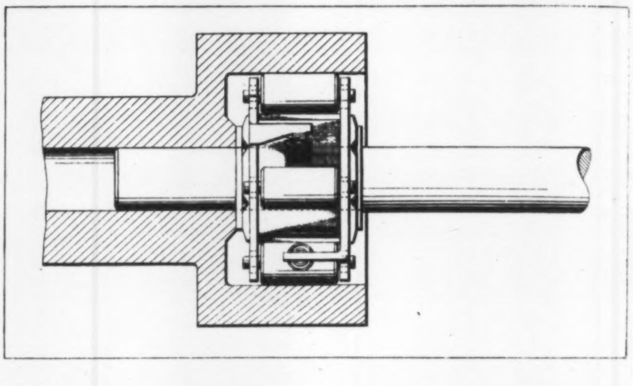
with time delay trip elements on circuit breakers, the shock absorber has no effect on the normal calibration and gradual operation, but prevents false operation by shock or vibration. In addition, the device eliminates the expensive mechanical counterbalancing required with conventional bimetal trip elements. Simple in construction, the design facilitates assembly and maintenance.

VISUAL FLOW INDICATION for lubricating systems is obtained magnetically with a clever check valve design assigned to McCord Corp. Covered in patent 2,638,582, the valve body has a loosely-mounted magnetic outer sleeve actuated by movements of a spring-loaded magnetic plunger which controls flow. Position of the sleeve indicates flow conditions as well as valve operation. Ralph F. Urso is the inventor.

ONE-WAY CLUTCHING at high torque capacity is obtained with a roller type clutch for small mechanisms described in patent 2,633,951. Assigned to High Precision Inc., the clutch uses a novel "cartridge" construction in which the drive unit, a self-contained assembly of rollers mounted on a center hub, fits into a cup-shaped driven member. In operation, the rollers wedge between the flat hub faces and the inner driven surface to provide a positive drive in one direction; overrunning causes the rollers to disengage and ride free. Clutching action is assisted by compression springs which are mounted to urge the rollers into engagement. Symmetrical and compact in arrangement, clutch construction simplifies production and maintenance and assures good dynamic balance characteristics. Assignors of the patent are Ermon F. Ayer and Samuel P. Caldwell.



TORQUE RESPONSIVE CONTROL of clutching action facilitates engagement and release of an overrunning disk clutch shown in patent 2,633,949. In the design assigned to Newton Clutch Co., power is trans-

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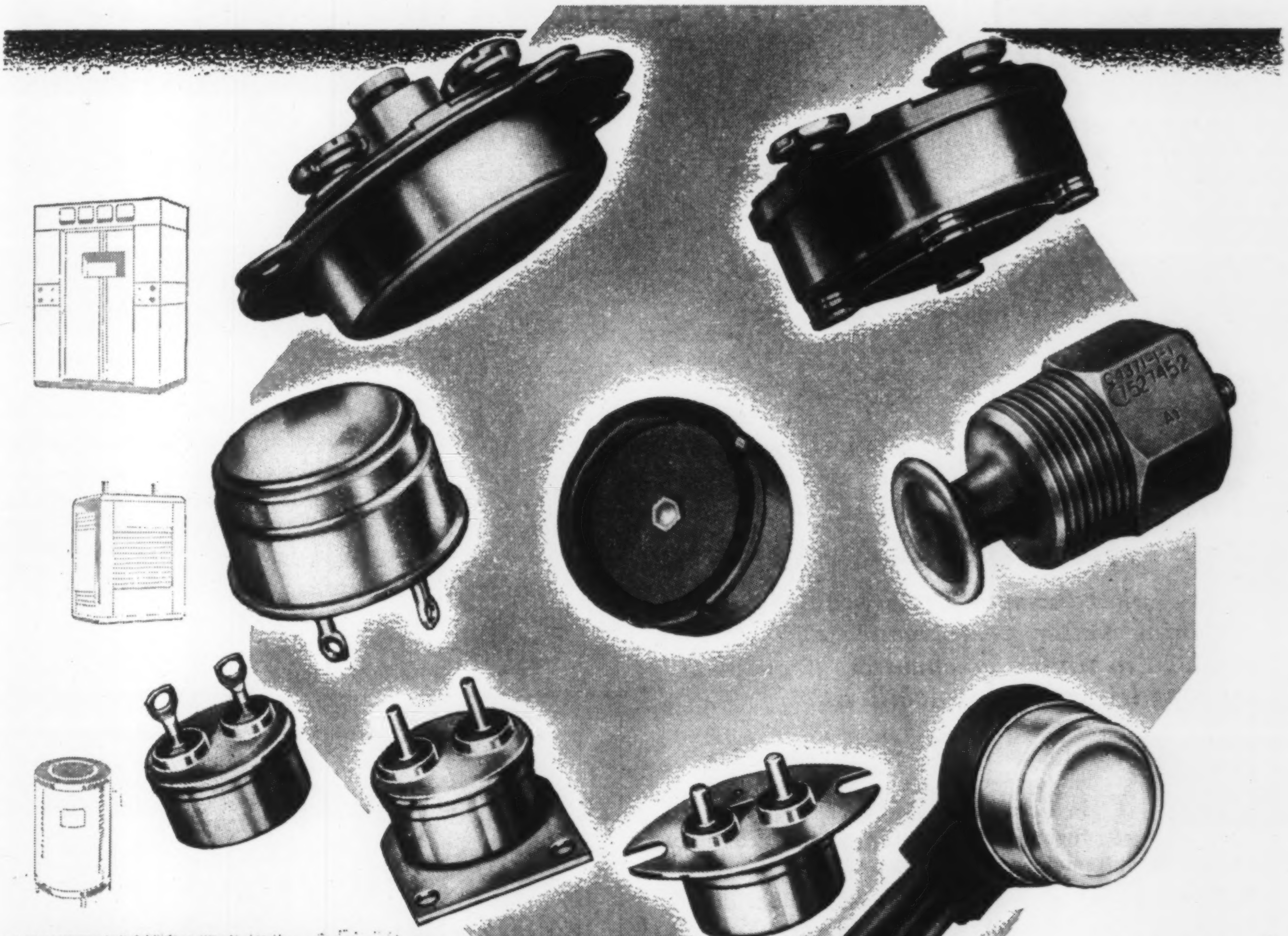

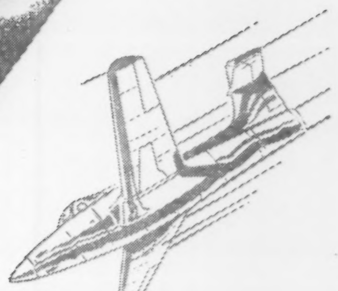

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Klixon Thermo-Snap Controls, hermetically sealed and open types, are available in many types, shapes and sizes, in a wide variety of operating temperature ranges.

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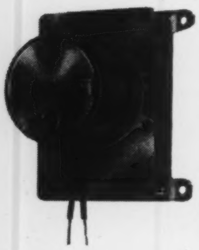
SYNCHRON Timing Motors pull up to 8oz. direct load at 1 RPM, operate efficiently at –40° to +140°F. They're available with gear trains to convert any speed . . . may be mounted in any position.



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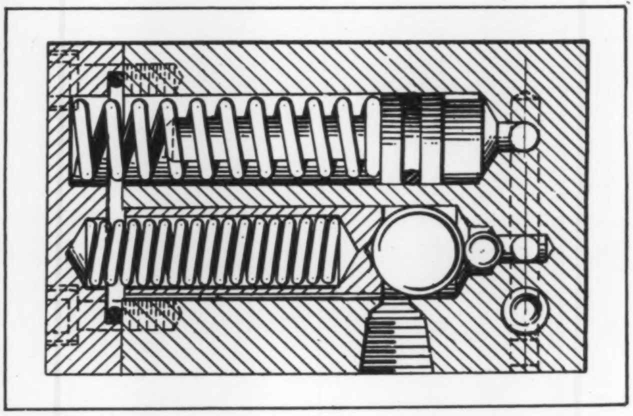
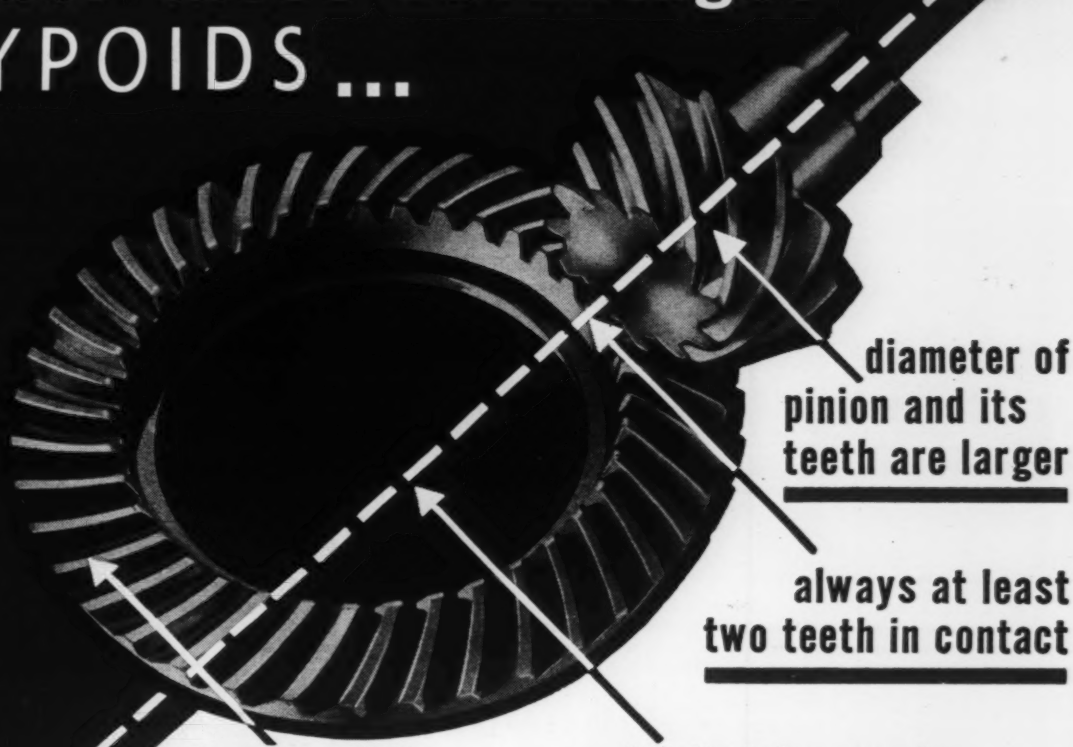
mitted to the driven member by a set of spline-mounted friction disks driven through a ratchet pawl connection on the driveshaft. A positive one-way drive is assured by the design which permits overrunning with the disks engaged. Clutching engagement is controlled by balls, mounted in tapered pockets in a rotating plate, which are actuated by direction of rotation and load to apply pressure against the disks. Normal tendency of the disks to separate when the clamping pressure is removed is assisted by spring-loaded pins to insure positive disengagement. Inventor of the patent is Francis L. Lavash.

AUTOMATIC FLUID BYPASS to prevent excessive pressure buildup in hydraulic circuits is afforded by the valve assigned to Goodman Mfg. Co. under patent 2,632,458. An invention of Joseph J. Slomer, the valve is designed for use with rotary or sleeve type control valves and incorporates a compensating action for momentary pressure surges caused by "dead spots" in the control valve piston. In normal operation, fluid is supplied from the pump through the valve to the main control valve. As pressure in the lines begins to build up, a spring-loaded piston is first actuated, opening an expansion chamber of limited capacity which has been designed to absorb momentary surges and thus prevent interruption of flow in the circuit. Prolonged excessive pressures, however, cause a spring-loaded ball check valve to unseat and permit fluid to be discharged back to the reservoir until pressures are again returned to normal.



ELECTROMAGNETIC CONTROL of fluid viscosity reduces operation slip and increases efficiency of torque converters and fluid couplings. In a design developed by Paul H. White, the driving impeller carries a separately-excited electromagnetic coil and operates in a fluid medium containing finely divided magnetic particles. Excitation of the coil generates a magnetic flux, freezing the magnetic particles in solu-

consider these advantages of HYPOIDS . . .



diameter of pinion and its teeth are larger

always at least two teeth in contact

circular pitch is greater

axis of pinion can be offset below or above gear

Like all "Phillie Gear" products, Hypoid Gears and Pinions made by Philadelphia are accurate. This assures the user of obtaining every advantage available from the hypoid offset design. Gears are generated on modern, precision machines; machined, heat-treated, hardened, and inspected by the latest methods. Philadelphia Hypoids and Spiral Bevel Gears range in size up to 49″ in diameter and 1 diametral pitch. Write us for further details about these or other "Phillie Gear" products.

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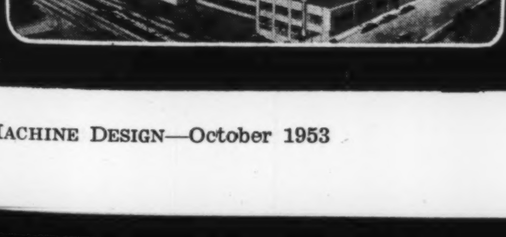
Intermittent
Sprockets

Philadelphia Gear Works, INC.



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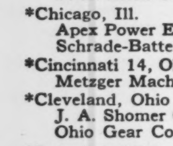
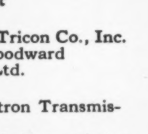
*Brooklyn 6, N. Y.
(Gears) Northside Leather Belting Co.
*Buffalo, N.Y.
*S. H. Pooley Belting Co.
F. E. Allen Co.
*Chicago, Ill.
Apex Power Equipment Co.
Schrade-Batterson Co.
*Cincinnati 14, Ohio
Metzger Machine Co.
*Cleveland, Ohio
J. A. Shomer Co.
Ohio Gear Co.
*Detroit 3, Mich.
Abrasive and Supply Co.
*Erie, Penn.
Cohen Industrial Supply
*Findlay, Ohio
Bearing & Transmission Co.
*Grand Rapids 2, Mich.
F. Raniville Co.
*Hagerstown, Md.
Hagerstown Equipment Co., Inc.
*Hoboken, New Jersey
(Gears) Crown Industrial Supply
Houston 3, Texas
Behring's Bearing Service, Inc.
*Indianapolis 2, Ind.
A. R. Young Company, Inc.
*N. Kansas City 16, Missouri
Sesco Engineering & Supply Corp.
*Los Angeles 1, Calif.
J. W. Minder Chain & Gear Co.
Louisville 2, Ky.
Alfred Halliday
*Massillon, Ohio
Hardware & Supply Co.
*Memphis 2, Tenn.
Memphis Bearing & Supply Co.
Milwaukee 11, Wisc.
A. F. Korf Co.
*Minneapolis 4, Minn.
Industrial Supply Co., Inc.
*Muskegon, Mich.
Lakeshore Machinery & Supply Co.
New Haven, Conn.
George G. Pragst
*New Orleans, La.
*(Gears) R. J. Tricon Co., Inc.
*(Reducers) Woodward Wight & Co., Ltd.
*New York, N. Y.
*(Reducers) Patron Transmission Co., Inc.
*(Gears) Atlantic Transmission & Gear Sales, Inc.
*Paterson 4, N. J.
(Gears) Bernstein Bros. Inc.
*Philadelphia, Pa.
*Robert L. Latimer Co.
*Rothman Belting & Equipment Co.
*Piqua, Ohio
Bornell Supply Co.
*Pittsburgh 30, Pa.
Standard Machinists Supply Co.
*Portland 14, Oregon
J. W. Minder Chain & Gear Co.
*Rochester 14, N.Y.
H. M. Cross & Son
*San Francisco 3, Calif.
Adam Hill Company
*St. Louis 4, Missouri
The Essmueller Co.
*Syracuse, N. Y.
U. & S., Inc.
*Toledo 12, Ohio
G. & J. Bearings & Supply Co.

IN CANADA, *Montreal, Quebec, John Braidwood & Sons, Ltd.
*Stocks Carried.

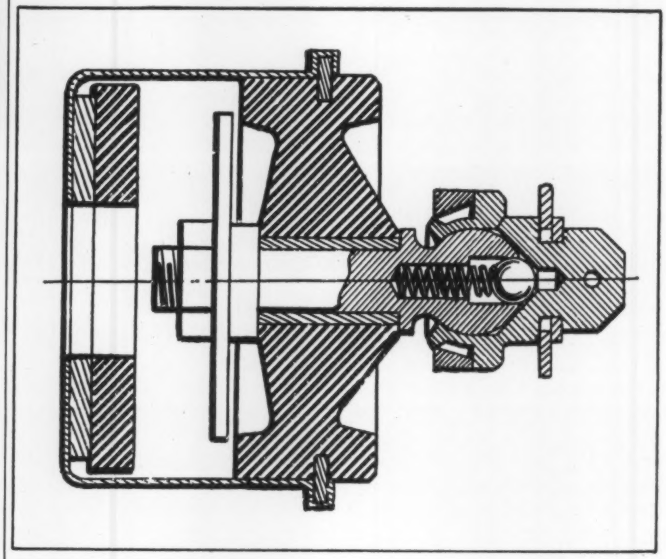


ESTABLISHED 1915
THE OHIO GEAR COMPANY
1338 EAST 179th STREET • CLEVELAND 10, OHIO
OHIO GEARS



tion and raising the fluid viscosity. Degree of slip is controlled by the magnitude of the voltage impressed on the coil as well as the contents of the fluid mixture. The device is outlined in patent 2,643,748.

CUSHIONED VIBRATION ABSORPTION in a mounting for delicate equipment resists high shock loads and prevents damage to fragile parts. Detailed in patent 2,634,069, the antivibration mount employs a ball-and-socket joint bolted to a rubber base and supported in a metal can to obtain universal damping action. Deformation of the rubber base under load coupled with a rolling action of the ball and socket joint serves to absorb both vertical and horizontal vibrations or shocks on the frame. Excessive deformation is prevented by a rubber disc and washer arrangement which act as a cushion stop to limit travel under abnormal loads. In addition, the self-aligning characteristic of the ball-and-socket joint facilitates assembly of mounted equipment. The patent has been assigned to Aircraft Radio Corp. by Frederick H. Drake and John E. Johanson.



UNIFORM SEALING ENGAGEMENT is maintained under misalignment or torsional oscillations by the shaft seal of patent 2,635,907. Designed for use with a shaft and housing or other similar rotating elements, the rubber or synthetic seal consists of two rigid metal-reinforced sealing elements connected by a flexible diaphragm. Eccentric shaft movements are absorbed by the action of the diaphragm, permitting the sealing elements to "float" and maintaining constant pressure of engagement. Both distortion and wear are minimized by the construction. Designer of the seal, Elmer F. Heimbuch, has assigned the patent to Brummer Mfg. Corp.

MACHINE DESIGN
NOVEMBER 1953

Custom-Built or Standard?

BASICALLY, a designer has a responsibility to his employer to design a product of competitive quality capable of being produced at a profit, and in quantities and at rates commensurate with its sales potential." Thus E. A. Green has put in a nutshell the challenge to the design engineer. Mr. Green's article, beginning overleaf, implements this challenge with a wealth of ideas on simplifying design to improve producibility—the key to profit, quantity and production rate.

In achieving simplicity and producibility of a complete machine the wise selection of purchased components and subassemblies plays just as vital a role as detail design. To some it may seem trite to stress this point, but there is overwhelming evidence that too many design engineers fail to make the extra effort to design for standard or off-the-shelf components. The result is a multitude of units specially designed and built only for particular applications.

In a recent speech J. C. Garrett said that, as an example of what is happening in the components field, the AiResearch division of his company is currently producing over 350 *different* models of air valves and regulators for aircraft. He went on to point out that the average cost of developing and qualifying a new model of hot-air valve today is approximately thirty to forty thousand dollars.

If design engineers of equipment using such components could adapt their designs to use valves already in production it requires no great imagination to visualize the savings in time, cost and effort that could be effected. When the multitude of components used in all types of machines is considered—electric motors and controls, hydraulic pumps, valves, motors and accumulators, clutches, couplings, bearings, fasteners, and a host of other items—the potentials in a "standard-conscious" attitude are boundless.

The custom-built special has its essential place in design, and without it progress would be slow indeed. But the special should never represent a cover-up for ignorance of a standard or lack of ingenuity in adapting a design to use an available standard.

Colin Carmichael
EDITOR